FIELD GUIDEBOOK
for a
SURVEY OF CENTRAL FLORIDA GEOLOGY

MIAMI GEOLOGICAL SOCIETY
1981 FIELDTRIP

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1981
Reprinted 1994

Miami Geological Society

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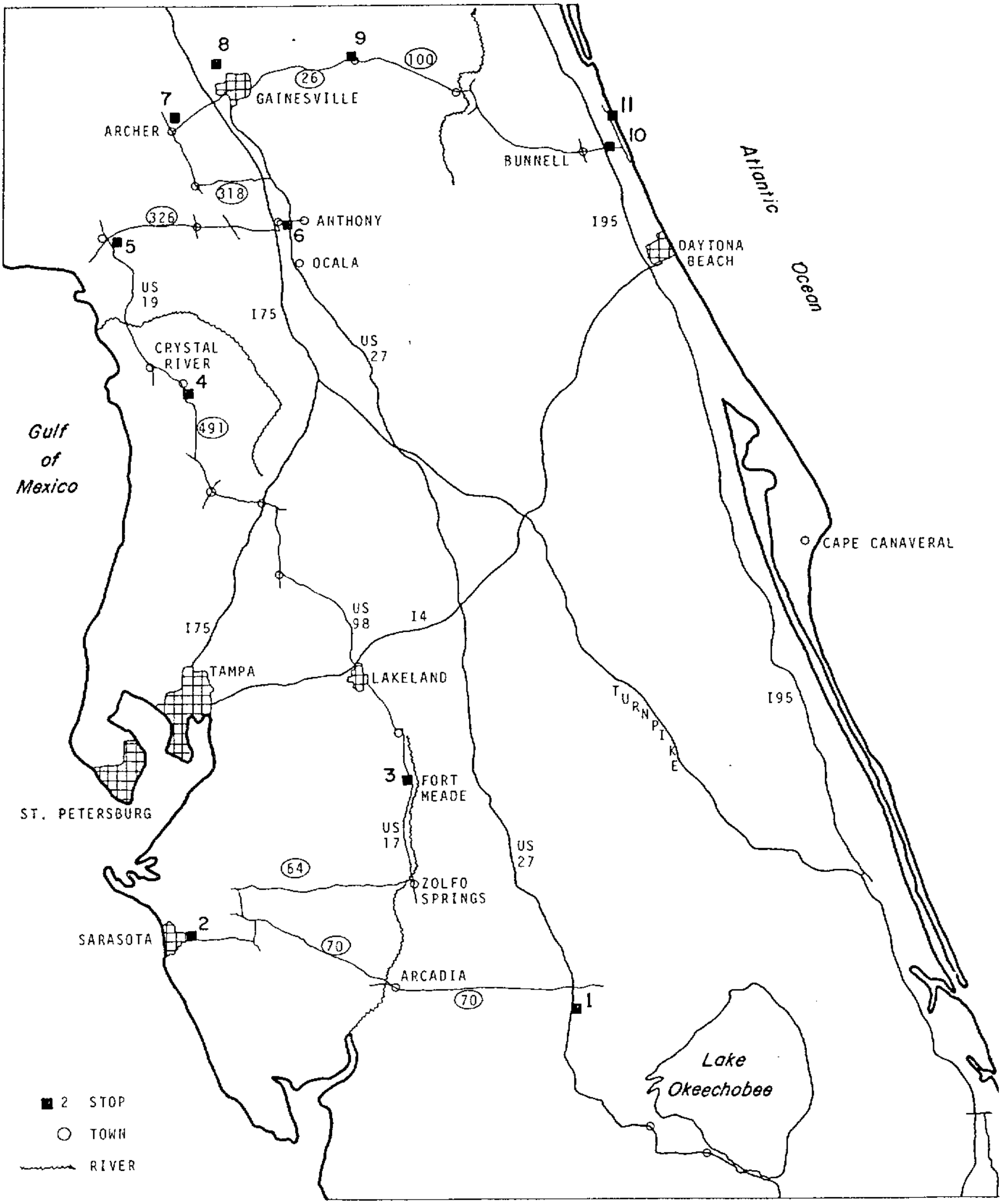

ACKNOWLEDGEMENTS

The Miami Geological Society and the fieldtrip leaders would like to express their thanks to the many individuals who have contributed in some way to the success of this field trip.

First we would like to express our gratitude to Muriel Hunter and S. David Webb who deserve particular thanks for their contributions at selected stops.

The following organizations and companies and their personnel are acknowledged for their permission to enter quarries or facilities and for their time and helpfulness: Warren Brothers, Inc. and Warren Lawson; Mobil Chemical, Inc. and Mr. Weisel, Nelson Fudge and Dan Cascalia; Crystal River Quarries, Inc. and Mr. Colitz and Mr. Klinger; Florida Limerock Gulf Hammock Mine and Dennis Murfa; and the Florida State Museum and S. David Webb, Graig Shaak, and Curt Auffenberg.

Manuscript preparation was in the hands of many whom deserve thanks: typed by Marjorie Hilligoss, Barbara Kiester, Nietha Long, Ruth Moore, Joy Shew, and Joan Stockman; drafted by Sandra and John Fish; edited by John Fish, Donald R. Moore, Sandra Fish, Susan Zachos, Louis Zachos, and Peter W. Harlem. Donald Hueur did the reproduction and printing.

Finally we want to thank Tom Scott, Patrick Gleason, and the South Florida Water Management District for their assistance and support.

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INTRODUCTION

This field trip is designed as a general survey of Florida's surface geology including lithologies, processes, and environments. We will look at typical sections which range in age from the oldest exposed rocks in Florida (Claiborne, Middle Eocene) to Late Pleistocene. Most stops represent either a typical lithology, a major process, or changes in lithology or processes. The oldest rocks, the dolomitic subtidal to supratidal Avon Park Formation will be observed in spoil and in cores. The Crystal River, Bumpnose and Suwannee limestones (Upper Eocene to Oligocene) are characteristically marine foram sands, chalks, molluscan and echinoid beds that fit typical carbonate shelf, bank or ramp models.

Major changes from carbonate deposition to clastic marine then non-marine sediments occurs in the Middle Miocene and later Miocene-Pliocene respectively. A stop at the Martin-Anthony Road-US441 intersection exhibits the subaerial exposure surface and related karstification between these two events. Stops in the Bone Valley phosphate district, Love Site, Devil's Millhopper, and Gradin Sand pit exhibit the marine and non-marine clastics of peninsular Florida. Finally, near coastal dominantly clastic deposits of shell beds (Sarasota), coquinas (Anastasis stops) and quartz sands (relict dune terraces and Recent beaches and dunes) will be observed.

The sections we will see on this field trip have been selected to show a wide range of the major geological processes to be found in central peninsular Florida. Very little attention will be placed on the subsurface; therefore, tectonic implications will only briefly be discussed at stops.

Major processes in the geological history of Florida

Several major categories of geological processes have determined the development of the Florida Platform. These processes are (1) biological productivity resulting in vast amounts of biogenic sediments, (2) influx of terriginous sediments by coastal and fluvial-alluvial processes from the north, (3) differential subsidence and uplift related to regional tectonic events, (4) erosion, weathering, and solution during exposure, and (5) static and eustatic sea level fluctuations. These processes are interrelated and major changes in relative rates through time of any process may affect the other processes resulting in recognizable differences in geological sections.

Changes in sea level both related to ice build up at the poles and subsidence or uplift are often difficult to separate and may be indirectly related. As many as 7 major sea level fluctuations since the middle Miocene (Table 1) have been recognized by workers in Florida. Brooks in Brooks et al (1966) illustrates his interpretations of sea level fluctuations and this is compared to the curve of Vail et al (1979) which is based on world wide information (Figure 1).

Vail et al (1979) show a major regression during the Late Oligocene which corresponds to the erosional unconformity at Stop 6. The Shoal River Formation at this stop coincides with their transgression in the middle Miocene. From Middle Miocene to Pleistocene a major regression occurred in stages which coincides with the major influx of clastics from the north as well as the uplift in the Ocala area.

During low sea level stands, weathering, erosion and solution are dominant processes which remove much of the section. These processes are responsible for the karstification, phosphatization and concentration by leaching, and reworking of older beds.

Description of the Florida Platform.

The Florida Bank or Platform is about 300 mi wide from shelf break to shelf break, with a maximum width of 135 mi of the bank exposed to form the Florida Peninsula. The width of peninsular Florida has changed through time from non-existent (in Cretaceous and early Tertiary times) to close to the entire width of the Platform during Pleistocene glacial epochs. The bank is bordered to the east and west by deep oceanic basins: the Florida Escarpment and Gulf of Mexico to the west and the Blake Plateau or Bahamas Bank and Atlantic Ocean to the east. The Florida Platform extends 450 mi southward from the continental portion of the North American Plate. The Florida Straits separate Florida from Cuba and the Bahamas to the south and southeast (Figure 2). Elevations in peninsular Florida rarely exceed 200'.

The Florida Platform consists of a thick sequence of Cretaceous and Tertiary carbonates resting on "basement" of Triassic red beds, Paleozoic sandstone, and igneous rocks. The igneous rocks can be divided into two groups. The first diabases, basalts, and rhyolites that date 87-183 mya and the second group of metabasalts, granites, and diorite which date 226-480 mya (Early Triassic to M. Pennsylvanian). The carbonate section is much thicker in the south (18,000'+) than in the north (approx 4,000') as shown in (Figure 3). Beds normally thicken to the east and west away from the peninsular arch (Figure 4).

The oldest outcropping rocks in the state are Claiborne (Middle Eocene) and a summary of the stratigraphic nomenclature of most surface strata is found in Figure 5.

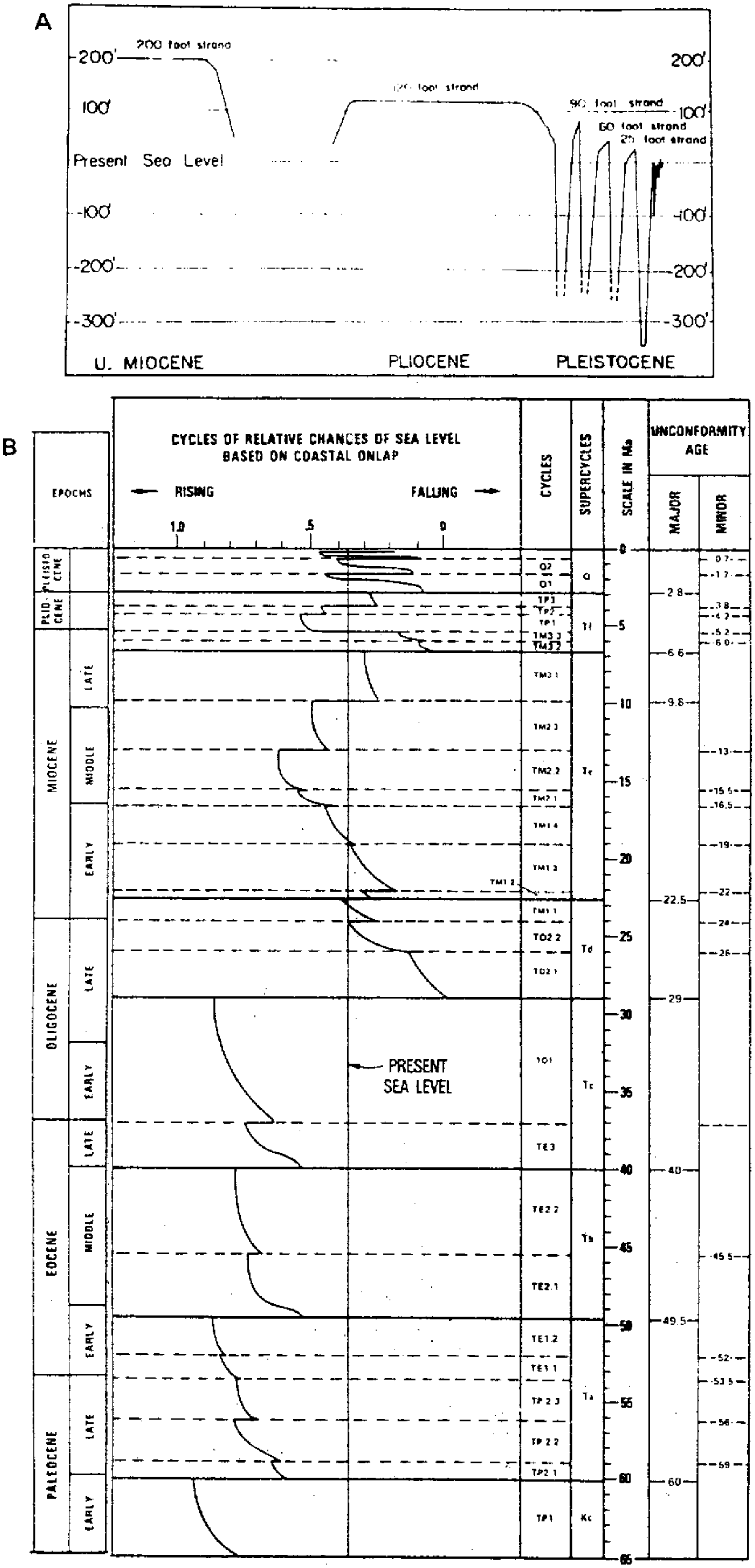


FIGURE 1: Comparison between A (Brooks, 1966) and B (Vail and Mitchum, 1979) sea level curves.

TABLE 1: Florida Marine Terraces (from Pirkle et. al., 1970).

Terrace	Elevation	Age
After Cooke (1945)		
Brandywine	270 feet	Aftonian
Coharie	215 feet	Yarmouth
Sunderland	170 feet	Yarmouth
Wicomico	100 feet	Sangamon
Penholoway	70 feet	Sangamon
Talbot	42 feet	Sangamon
Pamlico	25 feet	Wisconsin
After MacNeil (1949)		
Okefenokee	150 feet	Yarmouth
Wicomico	100 feet	Sangamon
Pamlico	25 to 35 feet	Wisconsin
Silver Bluff	8 to 10 feet	Recent
After Vernon (1951)		
Coharie	220 feet	Aftonian
Okefenokee	150 feet	Yarmouth
Wicomico	100 to 105 feet	Sangamon
Pamlico	25 to 30 feet	Wisconsin
After Alt and Brooks (1965)		
	215 to 250 feet	Upper Miocene
	90 to 100 feet	Pliocene
Insignificant stand	70 to 80 feet	Pliocene or Pleistocene
Insignificant stand	45 to 55 feet	Pliocene or Pleistocene
	25 to 30 feet	Pleistocene

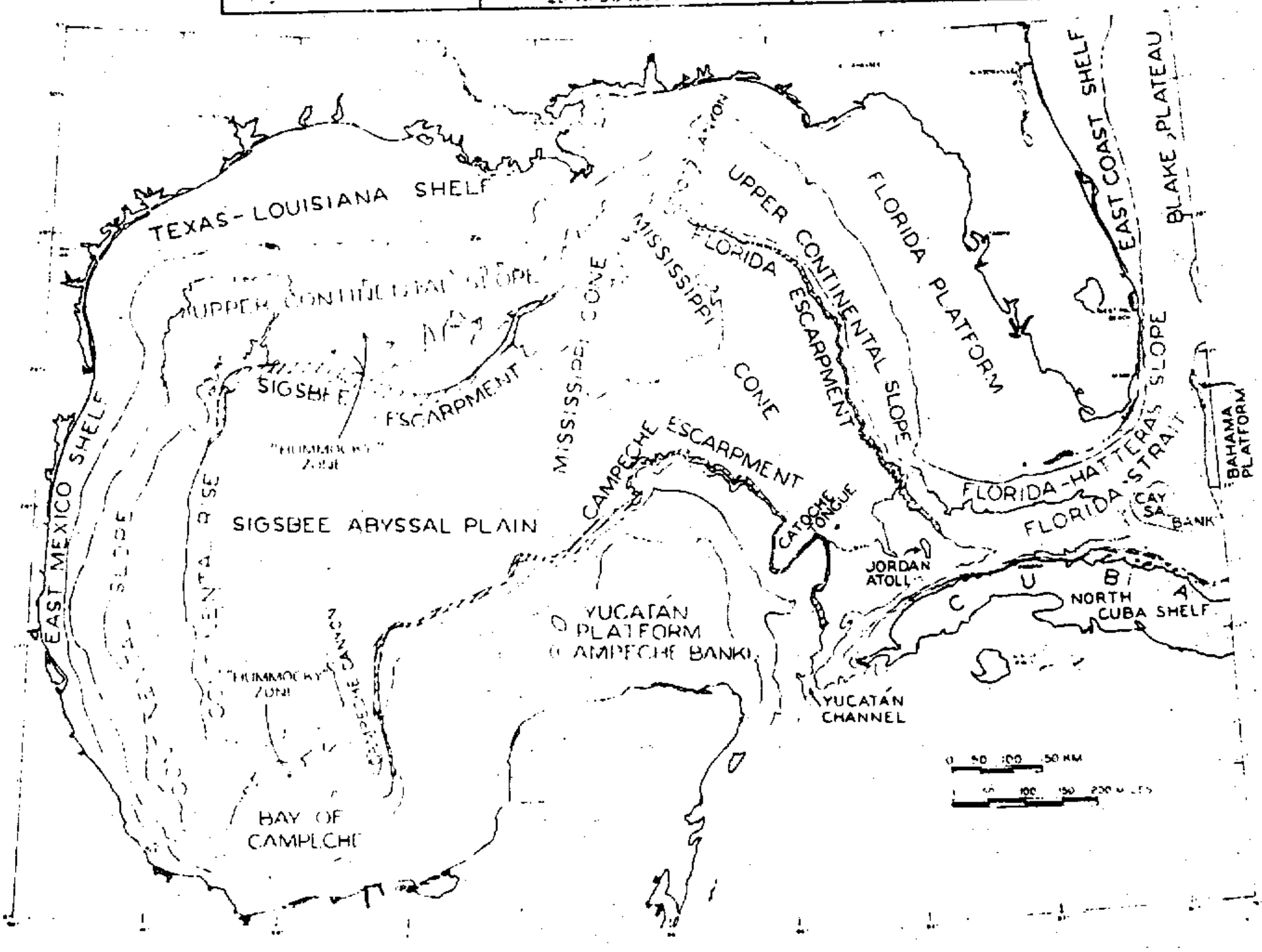


FIGURE 2: Topographic provinces of the Peninsular Florida Region (modified from Pain and Meyerhoff, 1970).

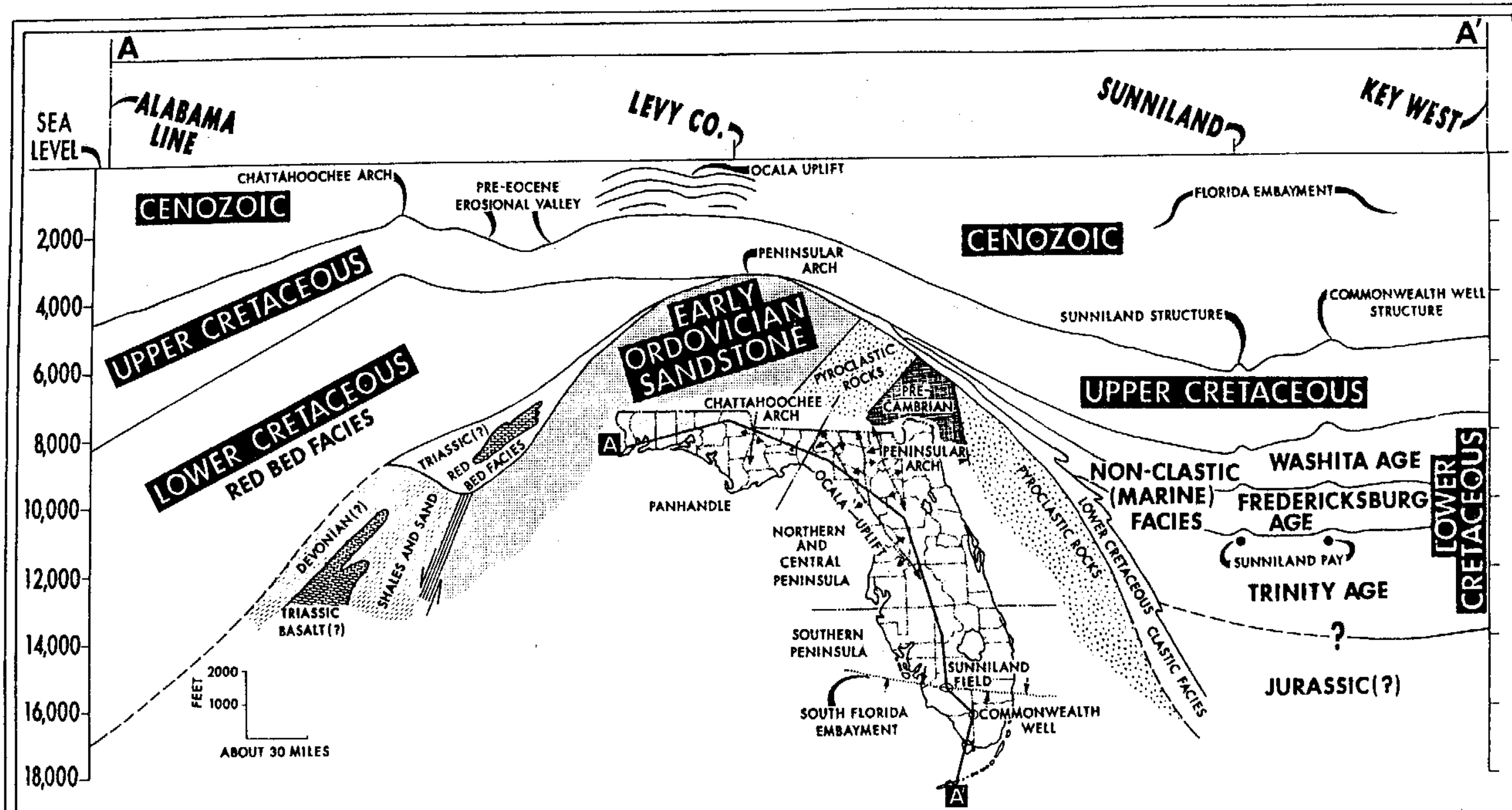


Figure 3. North to south geological cross-section of Florida (after Puri and Vernon, 1959).

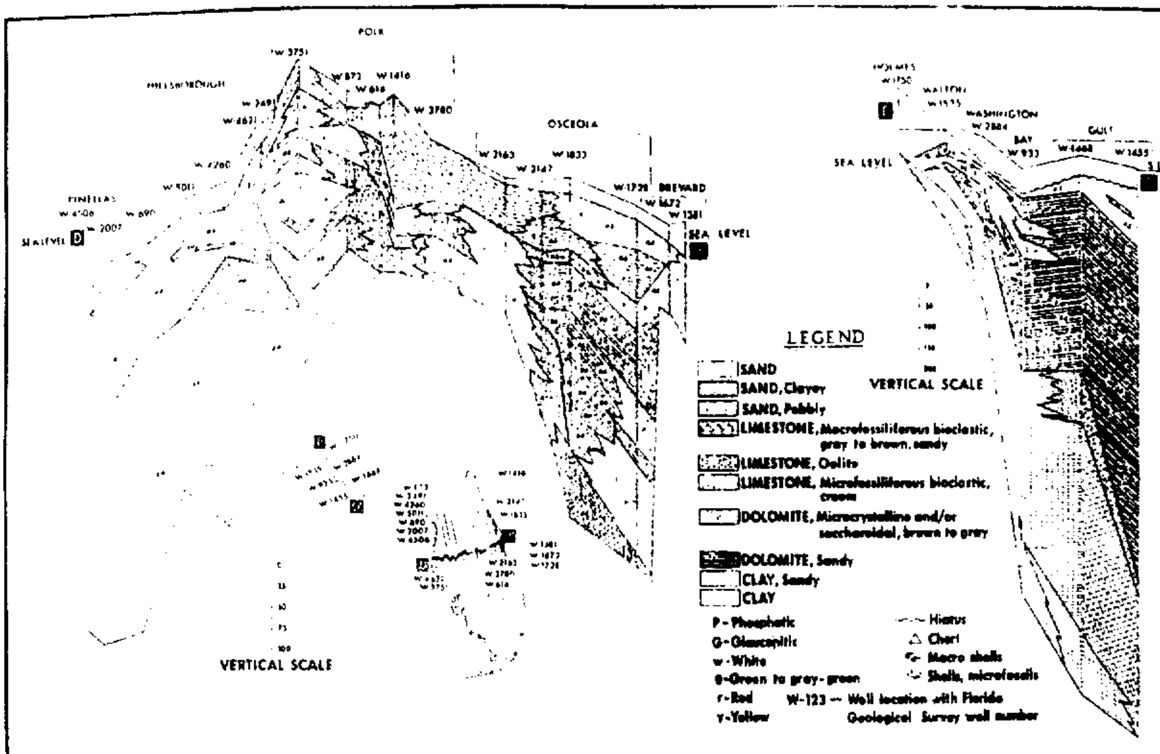


Figure 4. East to West cross section across Florida (from Puri, 1960)

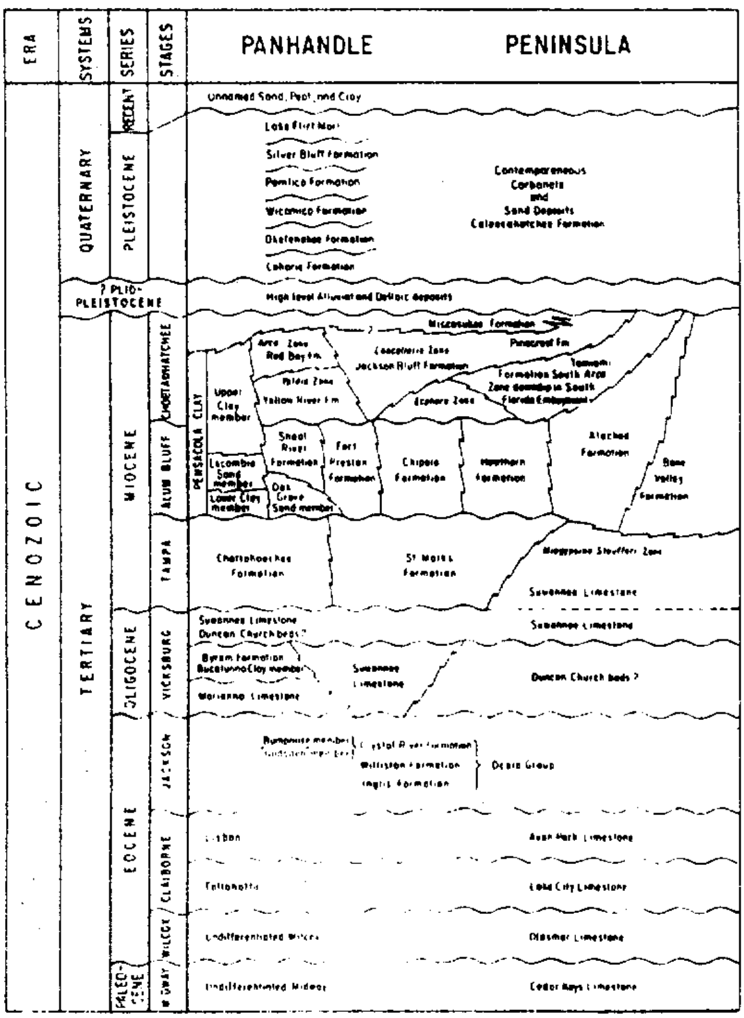


FIGURE 5: Florida stratigraphic nomenclature chart (from Puri, 1970).

ROAD LOG AND NARRATIVE

1981 MGS CENTRAL FLORIDA FIELDTRIP

DAY 1

Total Mileage	Mileage from preceding location	Travel guide
0.0	0.0	Leave 4 of M west parking lot, proceed west on Miller Road.
2.6	2.6	Turn right onto SR826 north (Palmetto Expressway).
12.	9.4	Exit onto US 27 north (Okeechobee Rd) toward Clewiston. Leaving the City of Miami we will move slowly northwestward down the gentle slope of the Miami Ridge composed of Late Pleistocene oolitic and skeletal limestones. In many areas the limestone surface is covered with thin veeners of quartz sand, calcitic mud, and organic peat. (On 27 past the Palmetto expressway) Melaleuca (*Melaleuca quinquenervia*), can be seen in tall dense stands and as sparse shrubs covering the peat surface of the eastern margin of the Everglades. Melaleuca is an exotic imported from Australia, and its rapid expansion may suggest stressed environmental conditions. This area, before development and water table drawdown, was covered by everglades type plant communities dominated by sawgrass (*Cladium jamaicensis*). Along this route northward to Lake Okeechobee the expansive, nearly flat Everglades with its water control structures will be observed. The Everglades, often referred to as the "River of Grass", originates at Lake Okeechobee, and terminates in the coastal swamps of Florida Bay. Along most of its path it is bounded by rock ridges to the east and west: The Pleistocene Miami oolite ridge to the East and the rocklands of the Big Cypress Swamp. The latter largely comprises Tamiami limestone with outliers of Fort Thompson and Miami limestones of Pliocene and Pleistocene ages respectively. Sawgrass, *Cladium jamaicensis*, dominates the landscape in the undeveloped Everglades with scattered tree islands dotting the landscape. The tree islands are located on organic soil highs in the extensive black organic peats which are characteristic of the Everglades. Hardwood hammocks throughout the rest of south Florida are normally located on bedrock highs. Melaleuca and *Schinus* (Brazilian Pepper) can be seen along the roads and canals, areas of impact to the natural system. To the east, Melaleuca can be seen encroaching westward into the Everglades. This encroachment is felt by many ecologists to be associated with lowering of the water table. Davis (1946) studied the thickness of the Everglades Peat deposits from Lake Okeechobee to the coastal marshes and at that time noted evidence of peat loss of as much as 10' south of Lake Okeechobee. Peat loss since that time can also be documented by watching the farm fields on the west side of the road. In several of these fields Davis measured as much as four feet of peat where plows are now turning limestone bedrock (approx 1.5'). Davis stated that peat was lost because of compaction associated with dewatering and subsequent oxidation. The oldest reported peat dates which suggest the onset of the present Everglades environment in this area are 6,000 yrs bp. This is interesting because it correlates well with Watts's (1975) pollen study of Lake Anne sediments (located on the southern part of the Lake Wales Ridge to the north) which provided strong evidence that the present plant communities of South Florida

have been active since 5,800 yrs bp. Coincidently, the oldest peat date in the Big Cypress is also 5,800 yrs bp (freshwater peat).

It should be noted that when the surface of the Everglades peat was higher, before dewatering, drainage patterns in South Florida may have been different. Water drains poorly through peats, and surface flow is also retarded and occurs only after the peat becomes saturated. Rivers through the Miami Coastal Ridge (such as the Miami River) may have carried more freshwater discharge, and it is postulated that many of the cypress sloughs in the Big Cypress may have been created, or at least influenced, by channelization of the sheet flow coming off the Everglades surface to the southwest. Mullet Slough presently catches most of this flow and diverts it to the south-east back into the Everglades. If Mullet Slough's peat surface was three feet higher this would not be the case.

Hoover Dike can be seen along the north side of the road after we pass South Bay. It is used to maintain water levels in Lake Okeechobee and was constructed after severe flooding occurred in Miami and along the South Lake Shore as a result of the hurricanes of 1926 and 1928.

Lake Okeechobee is the second largest freshwater lake within the borders of the United States. It occupies approximately 730 sq mi and its surface before drainage and diking stood as high as 20.5 ft but now rests at about 16 ft above mean sea level. The Lake has a maximum depth of about 17'. Brooks (1974) suggests that the Lake Okeechobee basin originated in the early Pleistocene as a slight depression and that the present Lake originated about 6,000 years bp.

Continuing westward on 27 the Everglades with its organic soils is left behind and a white, well sorted, fine to medium grained quartz sand topsoil can be seen. This region northward to the Lake Wales Ridge and westward to the Gulf of Mexico has been termed the sandy flatlands (Klein et al 1964) and is the largest physiographic unit in Glades and Hendry counties. White (1970) breaks the sandy flatland into the Okeechobee Plain, Caloosahatchee Incline and the Desoto Plain (Figure 6). The surface elevation ranges from 10 to 70 ft. The sands were deposited as marine terraces when sea level fluctuated between 25 to 70 ft above present during the Pleistocene; Penholoway terrace 42-70 ft. Talbot 30-42 ft, and Pamlico 10-30 ft.

The sandy flatland slopes gently to the south, is almost treeless, and has shallow depressions which may contain cypress. Fisheating Creek dissects this region and enters Lake Okeechobee which lies to the east.

Underlying the sands along the western margin of Lake Okeechobee, and westward along the Caloosahatchee River is the Caloosahatchee marl. This formation has the most restricted distribution of all Florida Neogene beds (personal communication, Druid Wilson; he suggests that most of what is referred to as Caloosahatchee is probably Unit A or Glades formation). The age of the Caloosahatchee has been widely debated and estimates range from Pliocene to Late Pleistocene because of the confusing fossil assemblages of fresh, marine invertebrates, and terrestrial vertebrates. The two pertinent facts are that the distribution is limited to the Caloosahatchee River valley and that the fossils and lateral facies are highly changeable, which suggest that this unit is mapable but probably deposited finally by fluvial processes. Fluvial processes would explain many of the graded beds in the Caloosahatchee, mixed fossil assemblages, and lateral complexity.

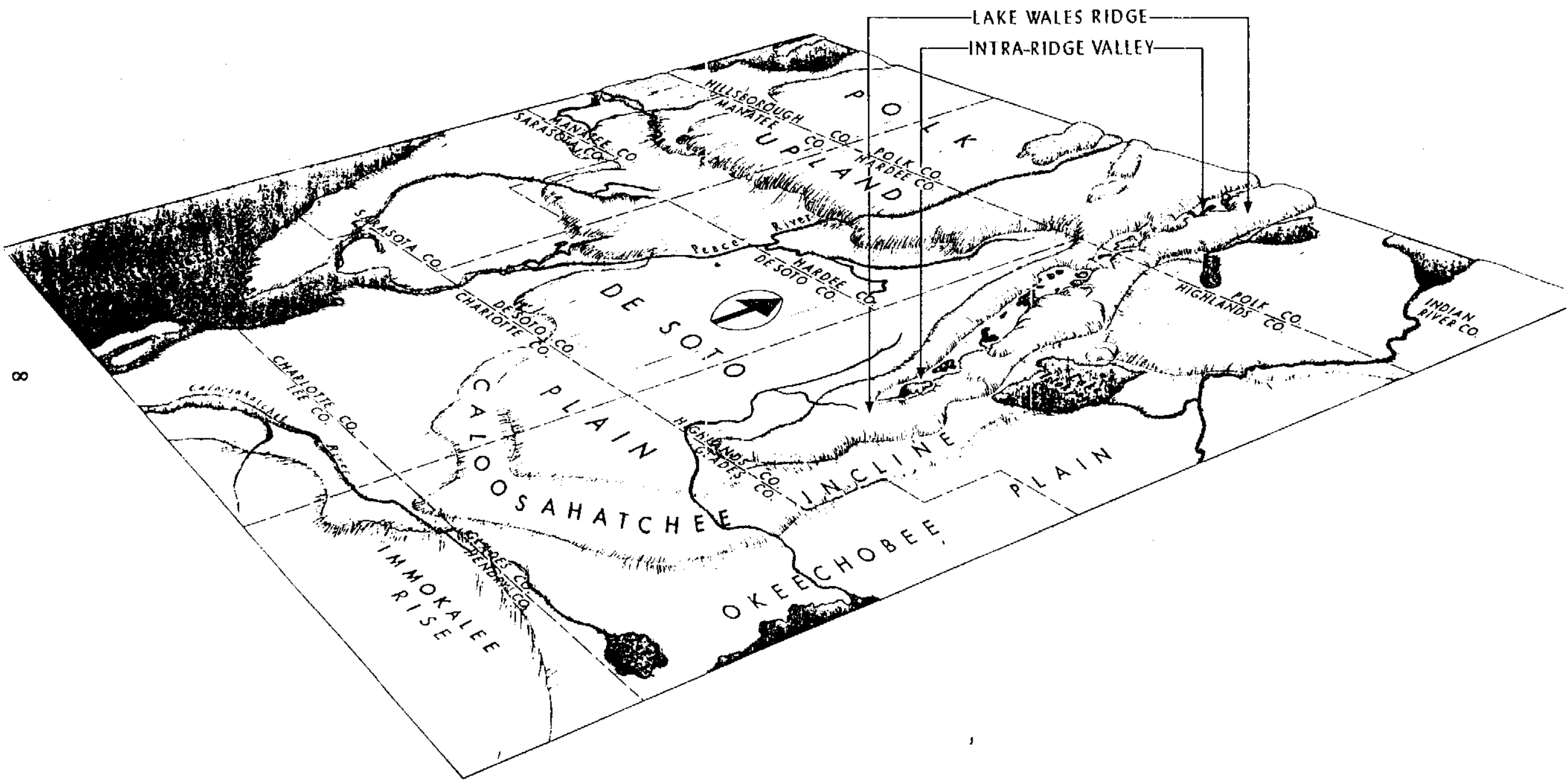


FIGURE 6: Physiographic map of central Peninsular Florida (from White, 1970).

			The age of deposition of the Caloosahatchee formation will probably turn out to be post middle Pliocene. There are obvious outcrops of Pliocene shell beds in the valley but most are reworked. The alternating patterns of fresh and marine limestones as reported probably represent alternating episodes of reworking of marine beds and calcitic mud deposition in the river's floodplain and in adjacent lakes such as Lake Flirt to the west, and do not represent fluctuations of Pleistocene sea levels. Away from the river, marine shell beds now are generally classified as Pinecrest (M.Pliocene) Unit A or Glades formation (E.Pleistocene) or Ft. Thompson formation (Pleistocene). Hunter (1978) reviews the nomenclature of the Caloosahatchee marl and Fort Thompson formations and interested readers are referred to it.
131.8	119.8		Change in elevation Leaving the Okeechobee Plain we climb up the Caloosahatchee Incline whose base is approximately 30-35' and crest is 60' in elevation and N-S width is 45-50 mi.
136.3	4.5	Stop No. 1:	Sand dune field: continue north on US 27.
143.0	6.7		Turn left onto SR 70
147.8	4.8		Begin descent from sand ridge onto lowlands. Traveling west we leave the Lake Wales Ridge and cross the Desoto Plain, a flat surface of white well sorted fine to medium quartz sand. Drainage systems in this region are poorly developed with numerous small basins, often lined with cypress that may drain downwards. As the Desoto Plain is traversed the elevation decreases from 75-85' near the Central Highlands to around 60'. Continuing west the Caloosahatchee Incline suddenly drops down to approximately 30' in elevation near Arcadia. The Caloosahatchee Incline dips more steeply along its western flank than to the south. The Peace River is entrenched 30-40' into the sands of the Desoto Plain. White (1970) believes the Desoto Plain to be a submarine plain probably deposited during the Wicomico sea level stand based on its elevation, lack of beach ridges, and relict shorelines.
174.4	26.6		Arcadia city limit
196.8	22.4		Myakka City
204.0	7.2		Turn left onto Verna Road
207.6	3.6		Turn right onto Fruitville Road (C 780)
220.3	12.7		Turn right onto Richardson Rd., (approx. 1 mi. west of I-75).
220.6	0.3	Lunch -	Picnic area on left side of road. Continue east on Richardson Rd., turn left after 0.5 mi. onto Newburn.
222.4	1.8	Stop No. 2:	Macasphalt quarry on right. Backtrack to Richardson and Fruitville Rd; go east 12.7 mi. on Fruitville Rd. to Verna Rd.; turn left and go north 3.6 mi.; turn left on SR 70 and go 2.3 mi west; turn right onto C-675.
248.3	25.9		Junction with SR 64. Turn right onto SR 64. Most of Sarasota County lies in the Gulf Coastal lowlands, which is formed from successive marine terraces. Traveling east and north of Sarasota we will again climb up onto the Desoto

Plain. Here the plain is narrow and we will climb up onto the Polk Upland with elevations between 100-130'. The toe of the Polk Upland scarp is at approximately 75-85' in elevation. The Bone Valley formation underlies most of the Polk Upland and much of the Desoto Plain. Solution has played only a small role in the development of the Polk uplands, and therefore surface streams are better developed here than in most areas of peninsular Florida. The Peace River drains much of this area. Several sudden dips in the road may be interpretated as ancient abandoned river channels, most of which are rich in phosphate and have been or will be mined. Stream dissection has created 50' of relief in the Polk Upland area.

280.3 32.0 Zolfo Springs. Turn left onto US 17; phosphate quarry on left 12 mi. north of Zolfo Springs.

299.2 18.9 Stop No. 3: Mobil chemical phosphate mine at north edge of Ft. Meade. Follow US 98 (also US 17) to Bartow, then US 98 to junction with US 92 in Lakeland; turn west onto US 92.

322.5 23.3 Best Western Motel: first night stop over

DAY 2

322.8 0.3 Leave motel going west on US 98 and 92; after 0.3 mile turn right on US 98. The elevation will gradually increase northward of Lakeland as we travel up the gentle eastern slope of the Brooksvill Ridge (Figure 7). The Brooksville Ridge is correlated with the Coharie-Okefenokee Sand Ridges of Vernon (1951). In this southern area the Pleistocene terrace deposits are thin and this segment of the Brooksville Ridge system, with its limestone outcrops, is termed the Tertiary Highlands.

White (1958) suggests that the Withlacoochee River originated as a lagoon behind an offshore bar during Okefenokee (150') or Coharie terraces (220'). The river valley has been trenched and refilled with sediment up to 100' thick and reaching depths 83' below present sea level (Vernon, 1951). White believes that the early Withlacoochee River followed the Hillsborough River drainage until recently when it aquired its present course through the Brooksville Ridge. He based his conclusion upon topography and river channel deposit depths. He further suggests that the route through the Brooksville Ridge is a newly formed gap produced by solution and that subsequent trenching has produced the present narrow channel in limestone bedrock near Dunnellon. The Brooksville Ridge runs north to central Citrus County and merges with the high rolling sand ridges along the western peninsula. These highlands comprise erosional remnant hills and ridges of Suwannee and Ocala limestones, sands and clays of the Alachua formation, and marine clays of the Hawthorne (Vernon, 1951). The highlands rise swiftly in elevation on the western border from 30' to 150'. The highest limestone hills in this area are 192' with no younger overburden. Early Pleistocene deposits are known from the tops of hills at elevations 220' suggesting that the highlands stood higher during the early Pleistocene and have subsequently been reduced. Present relief varies locally over short distances up to 130' (between 70 and 200') as a result of karstification.

The Crystal River and Suwannee Formations occur in the Morall rock pit in Pasco County. Most of the Oligocene Suwannee limestones have been highly weathered, leached and silicified forming a boulder zone on the Crystal River surface. Clays have infilled this weathered zone and a

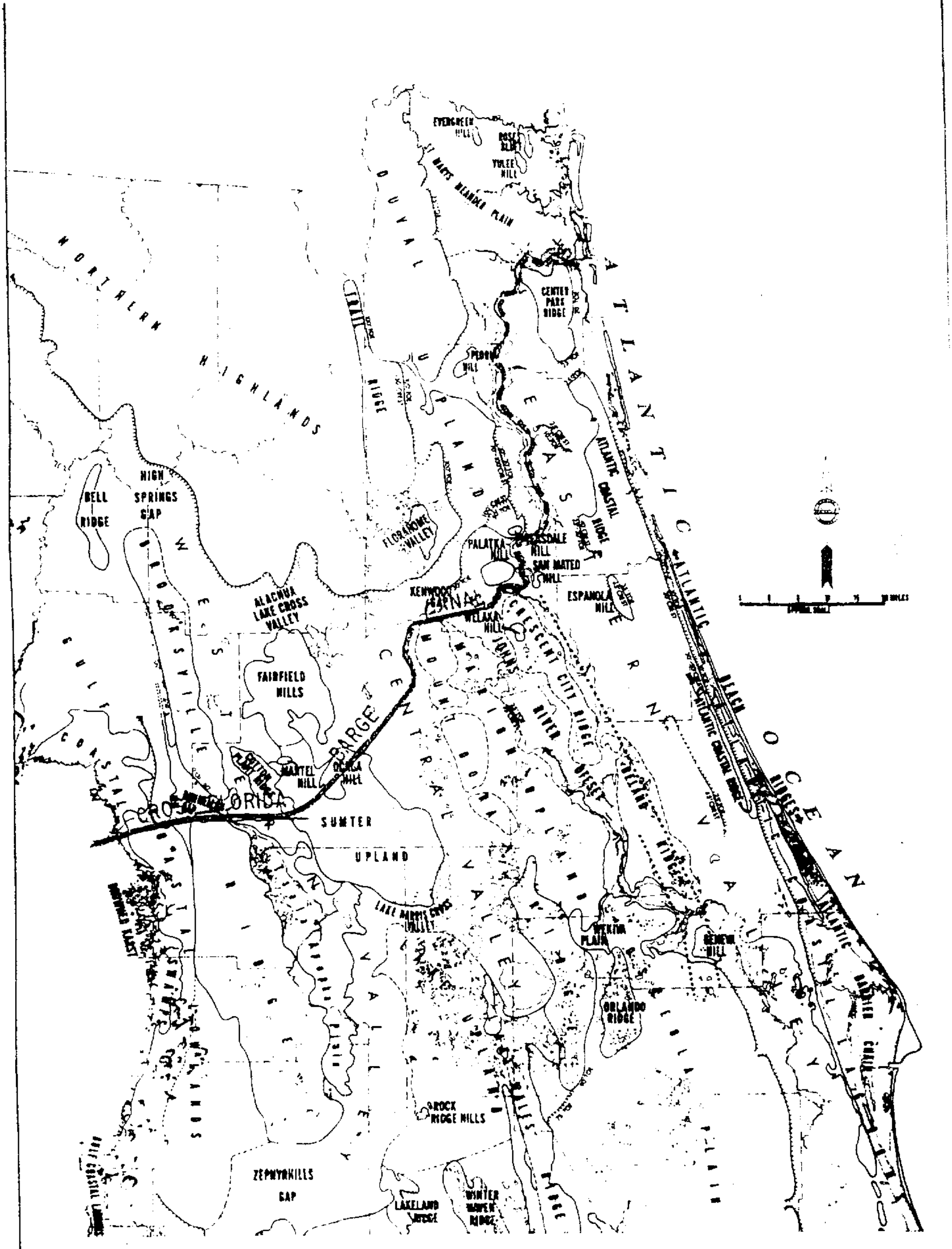


FIGURE 7: Physiographic map of north Peninsular Florida (from Puri, 1970).

			blanket of clean quartz sand covers the entire section. Diverse coral assemblages including *Stylophora*, *Acropora*, *Montastrea*, and numerous small corals are abundant in the silicified zone. These corals appear sporadically along this ridge northward to west of Gainesville.
344.9	22.1		Climb up into hilly country from flatlands
348.1	3.2		Join US 301; after 2 miles take US 98 bypass around Dade City.
355.3	7.2		Follow US 98 left; US 301 goes straight
359.2	3.9		Turn left at T intersection; US 98 joins SR 50
372.8	13.6		Follow US 98 right at intersection
380.6	7.8		Turn right (north) onto Highway 491 towards Lecanto
393.8	13.2	Stop No. 4:	Lecanto pit of Crystal River Quarries on right at end of crushed rock road; see Crystal River Formation.
403.4	9.6		Continue north on Highway 491 to Lecanto after 2.3 miles; turn left (west) onto SR 44 and continue to junction with US 19 and 98 in Crystal River; take US 19 north. Leaving the Tertiary Highlands to the east we will observe a very abrupt drop in slope down onto the Terraced Coastal Lowlands. The Lowlands along US 19 are sands deposited during the Pamlico stand when sea level was 25' higher than present. This sand blanket is absent further west along the coast where marine erosional processes have left an irregular rolling shelf.
413.6	10.2		Cross Florida Barge Canal. This canal was started in 1964 by the Army Corps of Engineers as a navigation channel to eliminate the need for transportation of materials by water around the Florida Peninsula. The project has, however, been halted because of economic and environmental impacts. The oldest rocks exposed in Florida are found on either side of the canal. The dolomites of Inglis and Avon Park formations of Claiborne (Middle Eocene) age are exposed. The Withlacoochee River cuts across the sandy Terraced Coastal Lowlands. The river is entrenched with steep banks cut into limestone with very little evidence of alluviation. Only a thin veneer of organic muds have been deposited along the river banks though there is a floodplain above Dunnellon in Marion County to the east.
431.4	17.8	Stop No. 5:	Florida Limerock Gulf Hammock Mine on right.
436.8	5.4	LUNCH:	Continue north on US 19 for 1.5 miles to Gulf Hammock then turn left (west) on C-326; proceed west along C-326 for 3.9 miles to Waccassa Bay County Park for lunch. The Waccasassa River originates as a poorly defined channel connecting swamps and ponds of Levy county in a valley up to three miles wide. Between the headwaters and SR 24 the broad river valley is filled with 14-18' of cross-bedded sands and clays. South of SR 24 the river runs through a limestone walled channel where there are additional feeder springs. A narrow flood plain of organic muds and sand is present in the lower portion where the river system merges with the coastline. In higher areas, *Spartina* and *Juncus* dominate the coastal marsh vegetation downstream. Occassional hammocks of sabal palms occur in the highest marsh, and red and

			black mangroves occur as a poorly developed fringe in some areas and on outer islands. Mangroves are found along the west coast as far north as the Cedar Key area.
440.7	3.9		Return to US 19; continue eastward on C-326
450.9	10.2		Reach summit of ridge and enter a subdued karstic terrane. Traveling east towards Ocala we again traverse the Coastal Lowlands and climb the Brooksville Ridge with its limestone bedrock covered by post-Miocene sediments. Once over the Brooksville Ridge we descend into the Western Valley whose floor ranges between 50-100' in elevation. In this valley many lakes such as Lake Stafford, Rainbow, Tsala and Apopka occur in a line formed along a karst zone. The Fairfield and Ocala Hills are a group of outliers of Tertiary limestone which reach 150-200' in elevation.
453.5	2.6		Junction with Highway 121; continue on C-326 eastbound.
455.1	1.6		"Lookout Mountain"
458.9	3.8		Intersection with US 41. Turn right on US 41 for 0.2 mi, then left on C-326. Follow C-326 through several intersections in next half mile.
465.9	7.0		Intersection with US 27; continue on C-326.
474.8	8.9		Junction with I-75; continue on C-326.
475.6	0.8		Left on old Highway 441 at Zuber.
477.5	1.9		Turn right (east) in Martin onto unmarked road to Anthony.
479.8	2.3	Stop No. 6:	Sanitary Landfill on Martin-Anthony road. Travel North will be along the eastern margin of the Fairfield Highlands with the Central Valley lying just to the east. The Central Valley contains many lakes such as Orange, Lochloosa and Newnans Lake which are all formed as products of solution. The Central Valley is approximately 15 mi wide and is dominated by the Oklawaha River system which drains northward into the St. John's River.
480.1	0.3		Left (north) US 441.
489.4	9.3		Left (west) on C-318. Pass under I-75 and continue on C-318.
504.3	14.9		In Williston turn north on US 41 and 27. The Western Valley west of Gainesville (Newberry limestone Plain) is a relatively flat plain of limestones of the Crystal River Formation with a thin veneer of Pleistocene quartz sands and occasional residual sediments of the Hawthorne Formation. Average elevations range from 60-65' to 100'. The coral *Siderastrea siderea* from the Hawthorn Formation is found as silicified residual boulders in this region north and west of Gainesville. The northern Highlands Plateau occupies much of Alachua County. As much as 140' of Hawthorn sediments cover the limestones of the Crystal River Formation. Elevations run from 200' in the west to 145-150' in the east. Over the Hawthorne a sequence of white quartz sands 0-30' thick is usually found. The area is poorly drained and is characterized by cypress hammocks and swamps between areas of pine-palmetto and hardwoods in higher regions. Along the

			margin of the Northern Highlands examples of headward erosion by streams are common features. This area is characterized by collapse sinks rather than level karst plain surfaces found where the Hawthorne overburden is absent.
514.3	10.0		Intersection with SR 24 in Archer. Continue north on US 41 and 27.
515.0	0.7	Stop No. 7:	Love Bone Bed. At fork after 0.7 mi. turn right onto SR 241 and proceed about 100 yards to site on right.
523.8	8.8		Return to Archer and go east on SR 24 toward Gainesville Pass under I-75 and turn into Days Inn about 0.1 mile beyond on right.
			DAY 3
523.8	0		Leave motel and drive north on I-75. After 2.7 mi. turn right onto highway 222 east. After 3.5 mi. turn left onto highway 232 (NW 43 rd St.). Bear left after 0.9 mi. and continue.
531.8	8.0	Stop No. 8:	Devils Millhopper State Geological Site on north side of road. Leave park returning back on Highway 232. Continue southward past intersection with Highway 222 toward SR 26.
535.8	4.0		Turn left onto SR 26; continue through Gainesville toward Grandin. East of Gainesville we continue on the Northern Highlands at about 150' in elevation. Quartz sands, silts, clays, and locally gravels occur in the Hawthorn (Citronelle) up to 150' in thickness. Most of the visible Hawthorne is non-marine, often with cross-bedded sands, and clay beds which appear as channel fillings or flood plain deposits often with silicified wood. Marine units are known from local outcrops especially further west and from well logs. Phosphatized internal pelecypod shells and silicified corals are abundant locally. The Hawthorne usually rests unconformably on limestones of Oligocene or Eocene age. The limestone surfaces are extremely irregular. The karst features of the limestone bedrock are expressed in the overburden which implies that dissolution has occured since the deposition of the Hawthorne sediments. Santa Fe Lake is an example of a lake formed by karstification processes in this region.
561.8	26.0		Turn right onto Highway 100. Note swamp on right. Southern Materials pit on left after 1.5 mi. Turn left on C-315 in Grandin, then left again onto dirt road immediately after crossing railroad tracks, and park.
564.9	3.1	Stop No. 9:	Keystone Sand Company Pit at Grandin. Return to Highway 100 and continue eastbound. East of Grandin the topography remains the same until the road surface descends into the Florahome Valley which is a large karst valley running n-s, with a relatively flat bottom. Once out of the Florahome Valley a sudden drop in elevation (around Carraway) to 100' occurs, which marks the transition from the Northern Highlands to the Duval Upland. The Duval Upland forms a flat sandy region which we cross at its southern extremity where it is only a few miles wide. Near Springside Park we drop again from the 70' toe of the Duval Uplands to the 20-30' surface of the Eastern Valley. The Eastern Valley contains a few highly irregular sand ridges of up to 45' in elevation and continues to the Atlantic Coastal Ridge. The major drainage system is the St. Johns River which runs almost the entire length of the Eastern Valley. The elevations of the Eastern Valley (20-

30') suggest that the St. Johns River originated consequent to a broad Pamlico lagoon that was enclosed by a barrier system which remains in relict form today as the Atlantic Coastal Ridge. White (1970), however, points out that land elevations to the north are often twice the elevations of the Pamlico terrace in the south and therefore the St. John's River must have formed prior to the Pamlico and coevolved with the later. He also shows that karstification played a major role in the development of the river system, and that dissolution was more intense northward. Associated with increased dissolution northward is the increased entrenchment and channelization of the river which begins in the south as a string of lakes and swamps connected by poorly defined and often braided channels. Lake Crescent originated as a solution lake along a trend, including Lake Disston to the south, parallel with the main river valley to the west. This trend may be an offset of the original St. Johns River valley.

582.9	18.0		Cross St. Johns River.
587.7	4.8		Left turn, continuing on Highway 100. A marked difference in vegetation occurs with elevation as we move eastward out of the Eastern Valley with its alternating pine-palmetto and wetlands up onto the Atlantic Coastal Ridge dominated by hardwoods such as live oak. The Atlantic coastal ridge appears to have been produced during Pamlico time when sea level was about 30' higher than present. The eastern topography of the ridge is often very similar to the present offshore profile found today. Quartz sand is the dominant sediment type with shell coquina and hash common in numerous areas, while carbonate sediments such as oolites dominate the extreme southern portion of the Atlantic Coastal Ridge.
611.4	23.7		Enter Bunnell; stay on Highway 100 through Bunnell.
616.1	4.7		Pass under I-95.
616.8	0.7	Stop No.10:	Bunnell Roadcut. Anastasia outcrop on north side of road. After stop continue eastbound on Highway 100; cross Intracoastal Waterway.
619.6	2.8		Turn left onto A1A paralleling the beach.
631.2	11.6		Entrance to Washington Oaks State Gardens. Immediate right into picnic area.
631.5	0.3	LUNCH & Stop No.11:	Washington Oaks State Gardens.
648.0	16.5		Retrace route back to intersection of Highway 100 and I-95. Take I-95 south.
802.6	154.6		End of I-95, exit right onto Okeechobee Rd. (SR 60); proceed west along Okeechobee Rd. for 0.7 miles, then turn left onto turnpike.
846.8	44.2		Exit off turnpike at exit No. 44 to rejoin I-95; toll is $1.10 for autos; turn left (east) at Palm Beach Gardens (SR 84); after 1.8 miles, turn right onto I-95 southbound.
928.0	81.2		End of I-95, merge into Dixie Highway (U.S.1); after 4.4 miles turn right onto Granada; after 0.2 mi. turn left onto Pisano; after 0.3 mi. turn left onto Campo Sand; after 0.5 mile turn left into U. Miami parking lot.
933.4	5.4		END OF TRIP

STOP DESCRIPTIONS

STOP NO. 1: SAND DUNE FIELD OF THE LAKE WALES RIDGE.

Just across the Highlands County line on US 27 the road climbs up to the toe of the Lake Wales Ridge. From the start of the ridge to Lake Istokpoga the ridge is only 1-2 mi. wide; north of Lake Istokpoga the ridge broadens rapidly into a westward curving arc 5-6 mi. wide (White, 1970).

The Lake Wales ridge (Figure 6) is the most persistent dune field system in peninsular Florida and runs from southern Highlands County to the northern end of the Ocala National Forest in Putnam County. The dunes are localized on the eastern side of the ridge for its entire length and the surface of the dunes are most often covered with palmetto scrub. Elevations range from 50-125' in the south to 70-150' in the north, with as much as 100' of relief expressed between trough and crest although normal relief ranges between 20-50'. Wave lengths are usually less than 500'. Relief may be the result not only of depositional processes but also of solution of calcareous sediments and limestone bedrock beneath the dune fields and subsequent aeolian processes. White (1958) believes that the Lake Wales Ridge may be an extension of the Trail Ridge to the north.

The dunes tend to be elongated in two directions at right angles to one another. The primary orientation is NW-SE and the secondary NE-SW. White (1958) points out that interpretation of these dune fields is hampered by the fact that the dune orientation coincides with the pattern of structural limeaments in the solution topography to the west.

The west side of the dune field zone grades laterally into the sandy flatlands. The east side of the dunes, however, ends in an abrupt scarp which probably represents a former shoreline. Correlations of dune systems is difficult because of the lack of useable fossils: very similar lithologies, reworking, erosion and elevations of crests may not be sufficient. Presently developing coastal dune systems along the Florida east coast exhibit considerable variation in elevation in the same dune system. For example, south of Jacksonville Beach, the third dune back from the water varies from 46' elevation in the north to 12' twenty miles further south.

As we look to the east along the secondary road at this stop several dune ridge systems are seen, each successively lower in elevation. This is a common phenomena on developing coasts such as south of Jacksonville Beach. Five successive dune ridges occur along the east coast with the third normally being the best developed.

STOP NO. 2: MACASPHALT QUARRY SARASOTA SHELL PIT

Hunter and Wise (1980) reviewed the definition and nomenclature of the Tamiami Formation. Olsson (1964) gave the name Pinecrest beds to shell beds which he believed to lie between the Tamiami limestone of Mansfield (1939) and the Caloosahatchee Marl. The Pinecrest beds have since been proposed as a member of the Upper Tamiami Formation (Hunter, 1968). The Lower Tamiami of Hunter has subsequently been placed in the Hawthorn (Hunter and Wise, 1980). Hunter (1968) included in the Upper Tamiami the Pinecrest Sand Member, Buckingham limestone Member, and Ochopee Limestone Member. Meeder (1979, 1980) is in total agreement with Hunter but includes an as yet unnamed coralline facies in the Tamiami which also contains the Pinecrest Sand Member molluscan assemblage. The age of the Pinecrest Sand Member of the Tamiami Formation has been assigned at one time or another to the Miocene through Pleistocene by numerous authors. Calcareous nannoplankton (Akers, 1974) and corals (Meeder, 1979) suggest an age of middle Pliocene.

The shell beds of the Macasphalt Quarry (formerly called Warren Brothers Pit) are placed in the Pinecrest Sand Member and represent one of the richest, high diversity molluscan assemblages to be found anywhere. The molluscan rich beds are all arenaceous often containing upwards to 80% fine to medium quartz sand. Although the biostratigraphic position of these beds is relatively well known, their paleoecology and environment of deposition is poorly understood. The rich molluscan beds represent obviously shallow open marine (5-35m) communities (Meeder, 1980; Moore, 1980). Paleoecological analysis of previously unpublished data indicates three major types of shell beds: (1) in situ beds with mollusks and corals in growth position, (2) reworked and transported beds accompanied by high deposition rates, and (3) minimally reworked beds with low deposition rates. Further subdivision, criteria for recognition, and interpretation, are presented in Table 2.

Table 2. Subdivision of the Pinecrest Shell beds into paleoecological units.

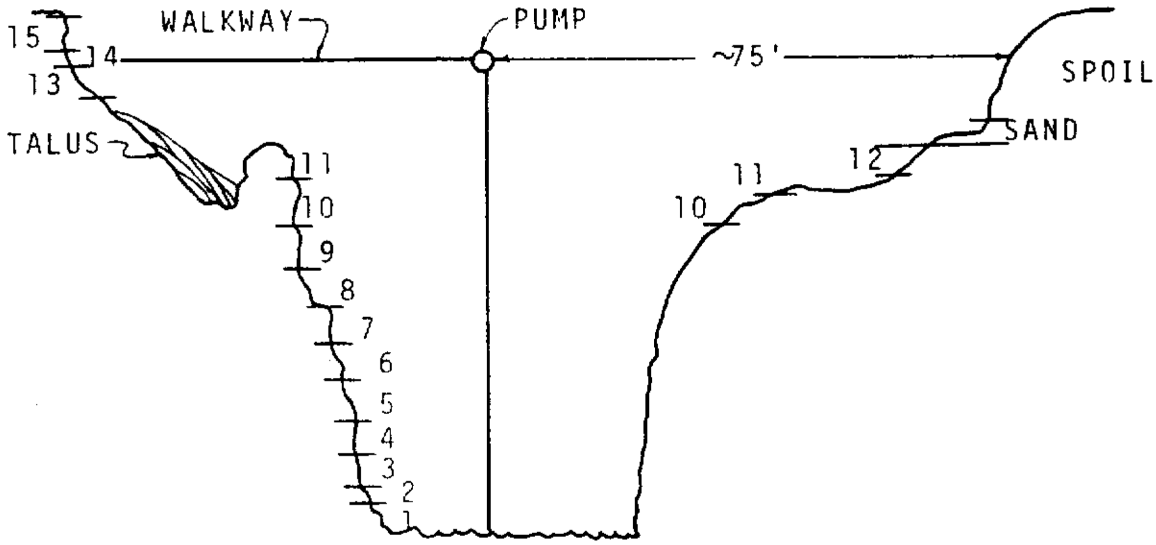
DIVISION	CRITERIA FOR RECOGNITION	INTERPRETATION
1. "in situ" growth orientation	mollusks and corals in growth position, esp. Vermitids; also barnacle encrustations on mollusks in growth position; continuous, irregular beds	life assemblage representing whatever specific community that is characterized
2. reworked-transported (high deposition rate) a. episodic energy events	well worn single valves, often broken, not encrusted by epi or cryptic faunal elements, fining upwards sequence common, current orientation and packing; discontinuous irregular beds or lensoidal.	storm deposit, shells exhumed from substrate and transported, not to be confused with a shell lag deposit.
b. daily high energy	highly fragmented shells, well worn, many small forms of bivalves, low angle bedding or absent.	lower beach facies or possible migrating high energy channel.
3. minimal reworking (low deposition rates) a. fine clays	clayey sand, low molluscan diversity (mostly pectens, oysters, barnacles, *Diplodonta*), layers of shell fragments, continuous bed with fossils usually occurring as stringers or mounds.	reworked beds in marine embayment such as Waccassasa Bay, offshore environs can't explain shell fragment layers.
b. no clays	gastropod predation, slightly worn and some broken, many bivalves intact, upper and some lower surfaces highly encrusted by bryozoans, sponges, corals, shells generally lack current orientation or packing; continuous regular beds.	possible storm lag, stabilized 2a in normally low deposition setting, or moderate energy low deposition biologically productive area.

The Pinecrest Sand Member as exposed in the Macasphalt Quarry exhibits distinctly different fossil assemblages and enivronments of deposition. Many units can be traced laterally for substantial distances while others appear to "come and go". An interesting aspect to these beds is their mixed lithology of carbonate, derived from local biological productivity, and clastic sediments of fine to medium quartz sand. The clastics have been transported into the system by nearshore processes and by possible reworking of older deposits which might explain the presence of the phosphate grains and broken shell beds in the lower units.

The upper units are completely unconsolidated whereas this same lithology further south is partially to entirely cemented. This is most likely a response to the differences in past water table histories in the two regions. The upper shell bed at Macasphalt Quarry exhibits carbonate leaching by percolating ground waters. The top of bed 7 also shows iron staining which may be suggestive of a short period of exposure. The composite section, bed descriptions, and illustrations are reproduced from Muriel Hunter's notes that she gave us for this purpose (Figure 8).

COMPOSITE SECTION, MACASPHALT QUARRY*

SURFACE BEDS, NORTH WALL, WEST OF PUMP		THICKNESS
Bed 15:	Brown sandy soil	4 ft.
Bed 14:	White unconsolidated quartz sand	1-2 ft.
Bed 13:	Buff unconsolidated quartz sand, top surface wavy and irregular (vertebrate fossils commonly found at base of this bed are placed in the Hemphillian and Blancan (John Waldrup and John Meeder)	4 ft.
TAMIAMI FORMATION, PINECREST SAND MEMBER, SOUTH SIDE OF PUMP EXCAVATION IN DITCH		
Bed 12:	White highly arenaceous shell hash, high diversity mulluscan fauna of small sized animals (½-1 in.), many extinct forms	½ ft.
Bed 11:	Arenaceous pecten hash, most pectens of *eboreus* type, numerous *Anadonta alba* or *A. schrammi*. Moderate to high mulluscan diversity containing the largest *Mercenaria* in the section	1 ft.
Bed 10:	Light gray arenaceous *Ostrea hiatensis* biostrome, contains low diversity molluscan fauna and micro-shell hash at base and in some places throughout the bed oysters are found as single valves and articulated	3 ft.
NORTH SIDE OF PUMP EXCAVATION, BENEATH PUMP WALK		
Bed 9:	Light gray arenaceous shell bed, moderate to high diversity, zones of pecten fragments throughout and at base of bed, not usually over 6" thick at base	3 ft.
Bed 8:	Dark gray *Ostrea hiatensis* biostrome, moderate diversity, *Mytiloconcha* zone up to 6" thick often found above oysters and large *murex* cf. *endivia* commonly found towards the base of the oysters	2 ft.
Bed 7:	Cream with iron seepage stains arenaceous molluscan rich *Vermicularia woodringi* bed nearly continuous highly irregular zone of upright vermicularia tubes usually in clusters, tubes often 12-14" in length, often associated with barnacles that live in sponges (this bed also contains several corals - J. Meeder).	½-1 ft.
Bed 6:	Cream with iron stains arenaceous *Strombus alatus* biostrome, low to moderate diversity dominated by *Strombus alatus*	1 ft.
Bed 5:	White shelly quartz sand, low to moderate diversity, many fragments, no *Chione ulocyma* observed	1 ft.
Bed 4:	White shelly quartz sand, similar to above but contains *Chione ulocyma* and *Sconsia hodgei*, higher diversity *Vermicularia sp?* and *Petaloconchus sp?* found horizontal orientated parallel to bedding, large black bone fragments at base.	½ ft.
	-Probably small hiatus here-	
Bed 3:	Gray clayey quartz sand with weathered crumbly shells, moderate diversity, small *Mercenaria sp* most abundant (probably *Ecphora* zone equivalent)	2 ft.
Bed 2:	Phosphatic clayey sand, no fossils observed, unconformable with lower bed	3 ft.
Bed 1:	Dark gray calcareous, clay, phosphatic, semi-consolidated, abundant fragments of *Pecten jeffersonius* and barnacles (similar to ones in Murdak Station Unit), chalky shell remains in Diplodonta molds, heavy *Ostrea disparilis* also common, indurated moldic gray limestone not found in place	2 ft.
	TOTAL	30 ft.



Muriel E. Hunter concludes from her biostratigraphic studies that the basal bed, bed 1, belongs to the Murdock Station Member which is equivalent to the <u>Arca</u> zone. Beds 2 through 12 are assigned to the Pinecrest Sand Member which is equivalent to the Jackson Bluff Formation in west Florida. Bed 3 is probably equivalent to the <u>Ecphore</u> zone.

<u>FIGURE 8</u>: Schematic cross-section of Warren Brothers New Pit, Sarasota, 2-15-71 by Muriel E. Hunter. Note: not to scale; now called MacAsphalt Quarry.

STOP NO. 3: MOBIL CHEMICAL, FT. MEADE PHOSPHATE PLANT

Central Florida phosphate mines produce nearly 30% of the world's supply of phosphate (Gurr, 1977). Most present production is from Hillsborough and Polk counties but southward expansion into Manatee, Hardee, and Desoto counties is underway. The phosphate mineral is usually a fluor-apatite found in a quartz sand and assorted clay mineral matrix (Gurr, 1977). The origin of the phosphate has remained a mystery, various theories ranging from guano derived (Vernon, 1951) to precipitation in a shallow marine basin. The latter theory required cold water from deep upwelling to flow across a shallow bank where precipitation occurred as the water warmed, forming phosphate pellets. The pellets were later reworked and concentrated (Riggs and Freas, 1968).

Cathcart (1968) suggested that the richest phosphate deposits formed in basins associated with structural highs. Central Florida phosphate mining district deposits form a thin sheet of sediments on the southern flank of the southward plunging Ocala Uplift (Gurr, 1977) and southward trending anticline, and the Hillsborough high (Cathcart, 1963a). The Hillsborough high is associated with stress relief faults with considerable displacement in the phosphate district (Cathcart, 1963b). Two formations are phosphate bearing; the Bone Valley Formation and the upper Hawthrone Formation. The Bone Valley Formation was first termed the Bone Valley Gravel (Matson and Clapp, 1909) and later changed to Bone Valley Formation (Cooke, 1945).

Crissinger (1977) identified 10 distinct units that recur throughout the Bone Valley district based upon vertebrate remains, lithology, and bedding structures. These units are presented according to their present topography and north-south distribution (Figure 9). These beds do not represent a definite stratigraphy.

Unit 0 is the Hawthorne Limestone. Hard, white, yellow to tan, massive, sometimes argillaceous dolomitic limestone; trace of phosphate sand; moldic marine shells of Miocene age; often lenticular; often interbedded with sandy or clayey phosphatic stringers; limestone/dolomite becomes cleaner lower in section; may represent the initial phosphate desposition in shallow sea.

Unit 1 is attapulgite rich sandy to clayey phosphatic Hawthorne bed interbedded with dolomite stringers. Color blank to blue-grey to green; clayey sand units widespread, lenticular, nearshore marine deposits with reworked vertebrates and abundant marine mollusc cast and molds; beds exhibit current sorting; river channels cut through this bed; probably lower Pliocene based upon vertebrates; up to 60' thick in south where it is massive and widespread.

Unit 2 is the typical "bed clays" of clay or silty clay with sand to pebble sized phosphate. Normal marine to intertidal; upper Miocene to middle Pliocene; probable origin from weathering of underlying strata; lacks good vertebrate fauna; upper contact shows signs of active reworking and clay clasts from this bed are found in upper units; probably Hawthorne.

Unit 3 is the sandy lower matrix pebble zone with high yields of low grade phosphate pebble. Exhibits thorough reworking and basal lag deposits on the bed clay contact; limestone fragments show phosphatic replacement; fauna is shallow to deep marine with terrestrial elements from older reworked beds representative of transgression; better developed in areas of higher relief, often filling sinkholes; less calcareous than underlying units; best developed where bed clay completely reworked; probably Pliocene, Lower Bone Valley Formation.

Unit 4 is the middle matrix sandy zone characterized by sandy clay to clayey sand mixtures of phosphate. Most common in-place fossil is Pliocene dugong; lack of terrestrial elements suggests transgression; unit has undergone supergene enrichment; color varies with phosphate content; paleo-soil on upper surface at 116' in elevation; probably middle Pliocene part of Lower Bone Valley Formation.

Unit 5 is the upper matrix pebble zone characterized by green to grey-green sandy clay containing phosphate pebbles. Montmorillonite clay; marine fauna except in upper beds which yield Pliocene horse fossils; usually reworked in southern region; terrestrial fauna ranges from lower Pliocene to Pleistocene, therefore reworked.

Unit 6 is a current reworked bed which contains lags of phosphate pebble, quartzite cobbles and mixed marine, fresh and terrestrial faunas. Usually light grey, pebbley sand or clayey sand; phosphate source not primary but from reworking; Pliocene to lowermost Pleistocene of Lower Bone Valley Formation.

Unit 7 was highly leached during upper Pliocene and Pleistocene, producing kaolin clays. Marks the extent of upper Pliocene sea level stand at about 70-90' in elevation; represents Upper Bone Valley Formation.

Unit 8 is a grey, tan to white quartz sand and clayey sand above the leached zone. Fauna is terrestrial middle Pliocene to near Recent; influx of clastics in early to middle Pleistocene associated with transgression; sand pockets cut through leached zone; discontinuous; barren of fauna represents active water courses during sea level fluctuations.

Unit 9 is altered Unit 8 with subsequent iron cementing and formation of hardpan which is associated with water table; mid-Pleistocene to Recent.

Unit 10 is water reworked matrix of active stream beds. Clays, sands, mucks, and phosphate pebble and sands reworked and deposited as lag deposits; river pebble phosphate.

Upper Hawthorne and Bone Valley deposition occurred east of the limestone outcrops and marks a major transition in deposition from marine carbonates to marine and nonmarine siliclastics. This reflects a major change in sediment source, load, and processes. Uplift may have been occurring to the west at this time (Vernon, 1951). If the Riggs and Freas (1968) model for phosphate deposition is correct, an upwelling of deep colder water along the coasts of Florida is needed. Major differences in 1) paleo-oceanography and climatology, 2) geographic position and orientation, 3) regional tectonic framework, or 4) a combination of the above must have existed from present. Perhaps the processes associated with the postulated upwelling were also tied into the new source of clastic sediments from the north.

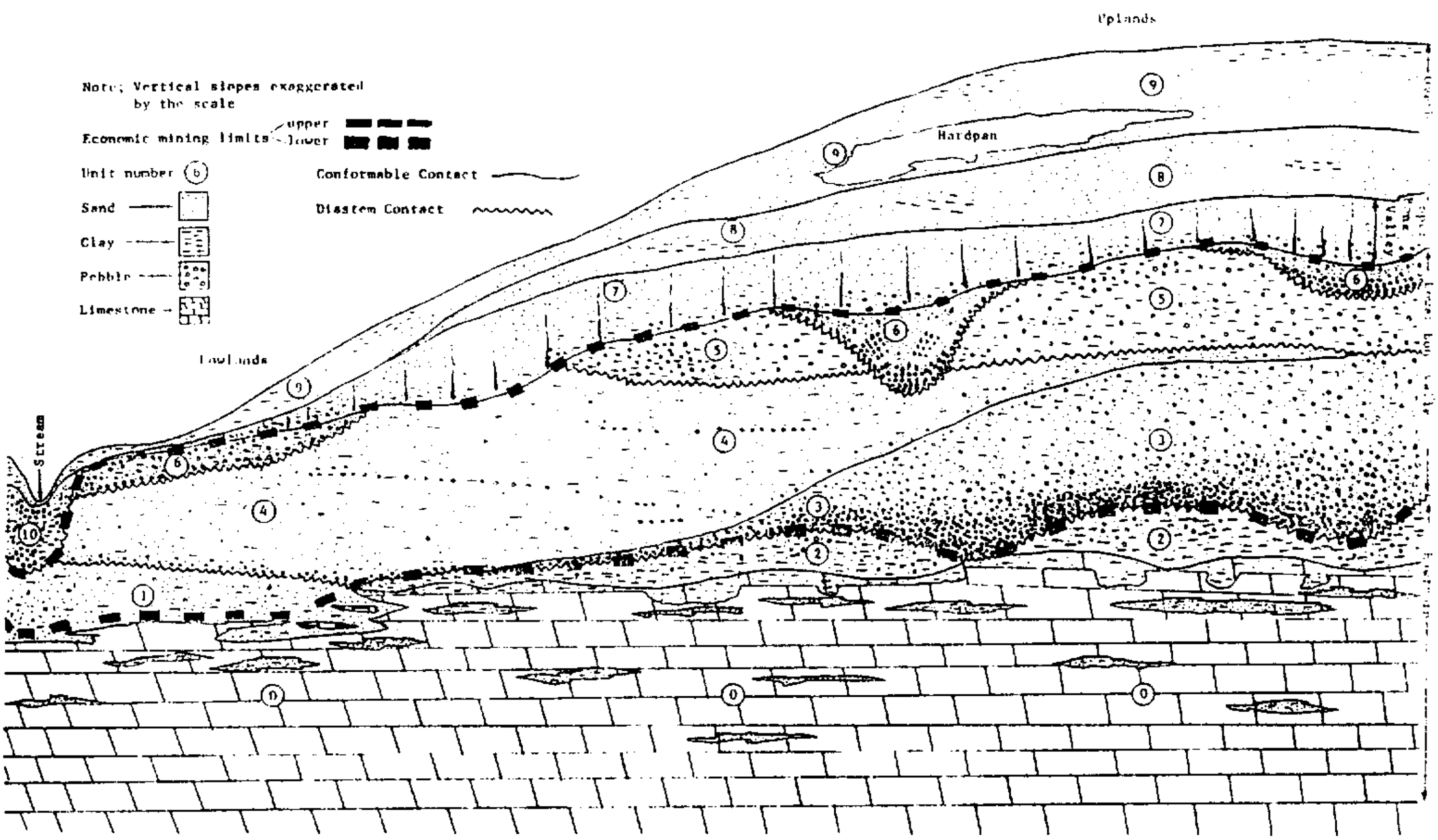


FIGURE 9: Typical cross-section through Bone Valley Phosphate Region (from Crissinger, 1970).

STOP NO. 4: CRYSTAL RIVER QUARRY, CITRUS COUNTY, FLORIDA
(rewritten from Muriel Hunter's notes)
(this stop has been moved to the Lecanto Limerock Quarry)

At this stop we will observe one of the larger exposed sections in peninsular Florida. The Crystal River (Jackson Eocene), Bumpnose Equivalent (lower Oligocene or Red Bluff Stage), and the Suwannee Limestone (Vicksburg) outcrop in the walls of the quarry. Williston (lower Jackson) and possibly Inglis (upper Claiborne, now referred to as Avon Park) fossils have been dredged from the lake in the floor of the quarry. The only remaining spoil from this lake now rests on the top of the hill to the east of the Quarry face.

Puri measured the type section for the Crystal River Quarry from the highest point on the then exposed quarry face in 1948. Puri reportedly was lowered by rope down the face for sampling (personal communication, Joe Banks to Muriel Hunter). Between 1948 and 1962-63 the quarry was enlarged and the lake was dug exposing a wedge of sediments not present at the type section (Figure 10). This sediment is a soft grey massive very fine grained limestone (possibly argillaceous) that contains common *Clypeaster* cf. *C. rogersi*, *Paraster* sp (intermediate between *P. armiger* and *P. americanus* of Mississippi and Alabama sections), and *Spirulaea vernoni*. This bed is believed to be Lower Oligocene in age and equivalent to the Bumpnose (Moore, 1955).

Solution pipes and occasional small caves are present throughout the pit. Construction workers in 1970 reported that a large crack crossed the floor of the quarry at one point where they were clearing. The top part of the Ocala Limestone (Crystal River Formation) is weathered to pinnacles and on the hill by the entrance road it is practically non-existent. At this point, the Oligocene limestones are almost at road level. Elsewhere in the pit they drape over the pinnacles and fill the hollows. The newly exposed wedge appears to have been deposited against one such pinnacle, and then both the wedge and pinnacle to have been covered by later Oligocene sediments. Figure 11 shows the draping of the Oligocene over the Ocala, and the wedge of soft Oligocene sediment between the two units.

The sediment of this wedge was seen at the top of the quarry immediately above as spoil. It was not possible to reach the outcrop because of the vertical face. From a distance it seemed as if there was a clay bed at both top and bottom of the wedge, with the clays above and below merging to form Puri's clay of bed 7. (Figure 12).

Numerous slump features are to be seen around the pit. Some have been called faults (Vernon, 1951).

The irregularity of thickness and elevation of the Oligocene and Eocene limestones in this pit emphasizes the variations in sections that might be expected over even larger distances. I believe it might safely be said that two holes drilled 50 or 75 feet apart at any point in this pit would not exhibit the same section, at least in above sea-level beds. It also emphasizes the need to know the parts of the Ocala, so that we may know whether section is missing by erosion, whether the uneven tops are the result of topography, etc.

The boulders dredged from the lake (Figure 10) were of hard granular limestone with an Inglis fauna containing the following fossils:

Ectinochilus or *Dientomochilus* n. sp.
Platyoptera extenta (occurs in Williston and Moody's Branch)
Athleta arangia (Inglis)
Agaronia inglisia (Inglis)
Pseudocrommium brucei (Inglis)
Caricella obsoleta (Inglis)
Xenophora sp (Inglis)
Cypraedia fenestralis (Ocala and Inglis)
Trigoniocardium protoaliculum (Inglis)
Crassatella inglisia (Inglis)
Fimbria vernoni (Inglis)
Venericardia scabricostata (Inglis)
Pteria or *Pinctada* sp (Inglis)

This fauna contains many typical Inglis elements but is not a complete Inglis fauna with such characteristic species as *Velates*, *Bellatara* and *Volsella* missing. *Platyoptera extenta* however, has never been reported from the typical Inglis fauna. This presents a problem: is this a new bio facies of the Inglis (now Avon Park) or of the rubble zone in the Williston?

Vertical walls and vegetation overgrowth prevents easy detailed collecting of the fossils from the Crystal River limestone except from spoil. The rich molluscan and echinoid beds are not dominant in this pit and most beds in the pit are microfossiliferous. Very fine grained chalky white limestone almost devoid of visible fossils alternates with foram rich sands, especially leps and nummulities. These foram rich beds usually also contain shell and echinoid fragments, bryozoans and occasional molluscs. Molluscs tend to be concentrated in moldic, harder thin beds which are not common at this quarry. Forams are often found floating in the fine grained matrix or packed together in lenses, the later often with preferred orientation suggestive of

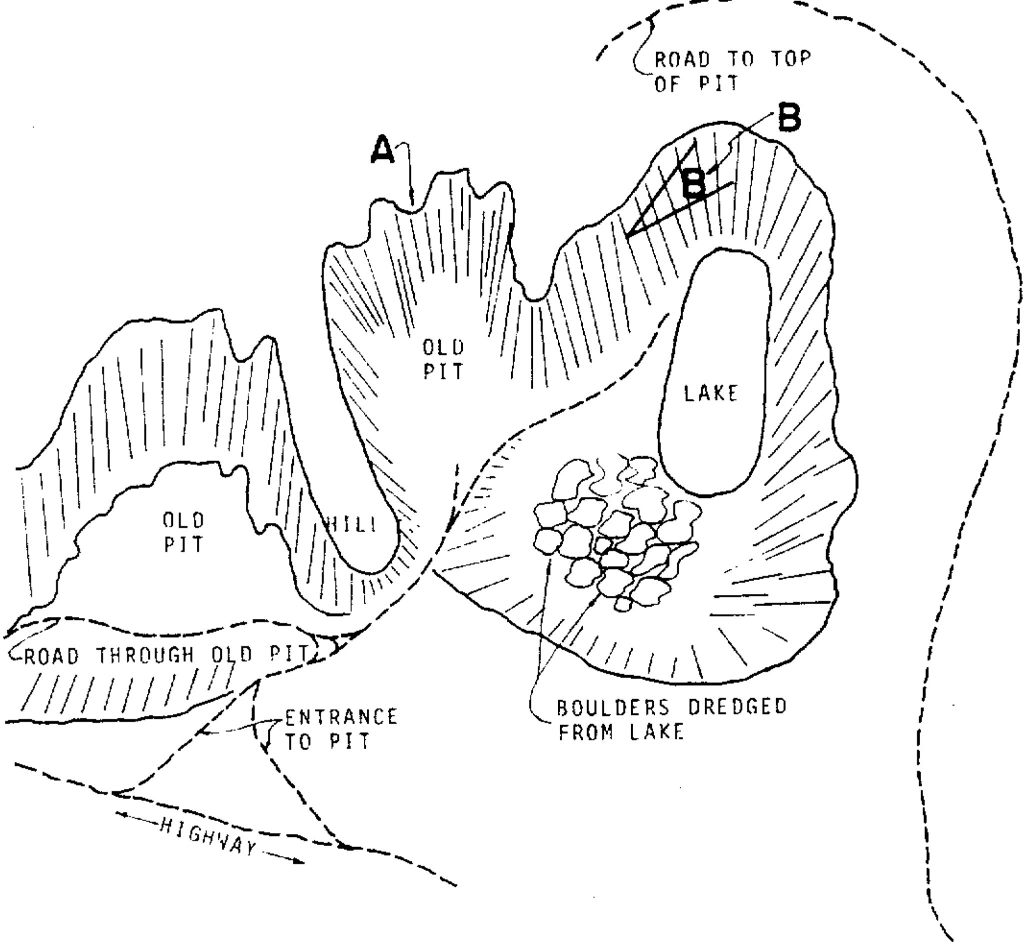


FIGURE 10: Sketch of Crystal River Quarry with location of sections in pit.
A: Florida Geological Survey type section (Fla. Geol. Surv. Bull. 33, p 168).
B: Wedge of lower Oligocene (15-20') sediments not included in Survey section - exposed after original section measured.

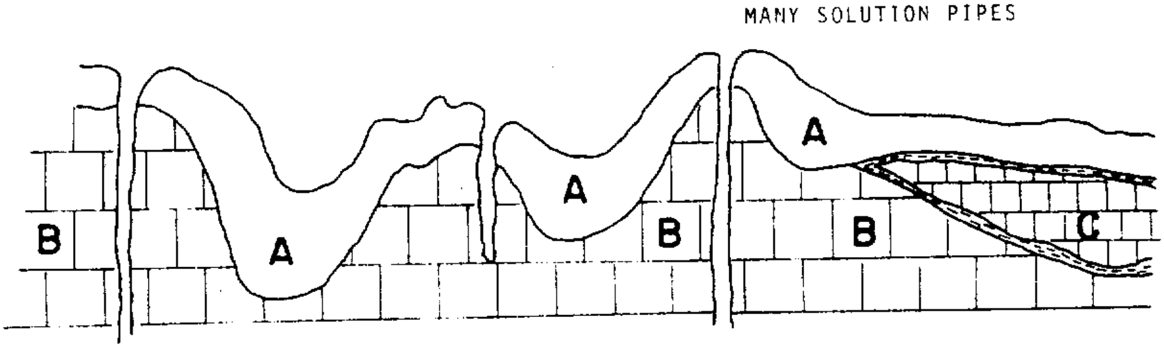


FIGURE 11: Sediments of Oligocene age draping over the uneven surface of the Ocala limestone.
A: Oligocene limestone of the survey's section.
B: Crystal River Formation after Puri.
C: 15' wedge of soft limestone of early Oligocene age with clay at the top and base.

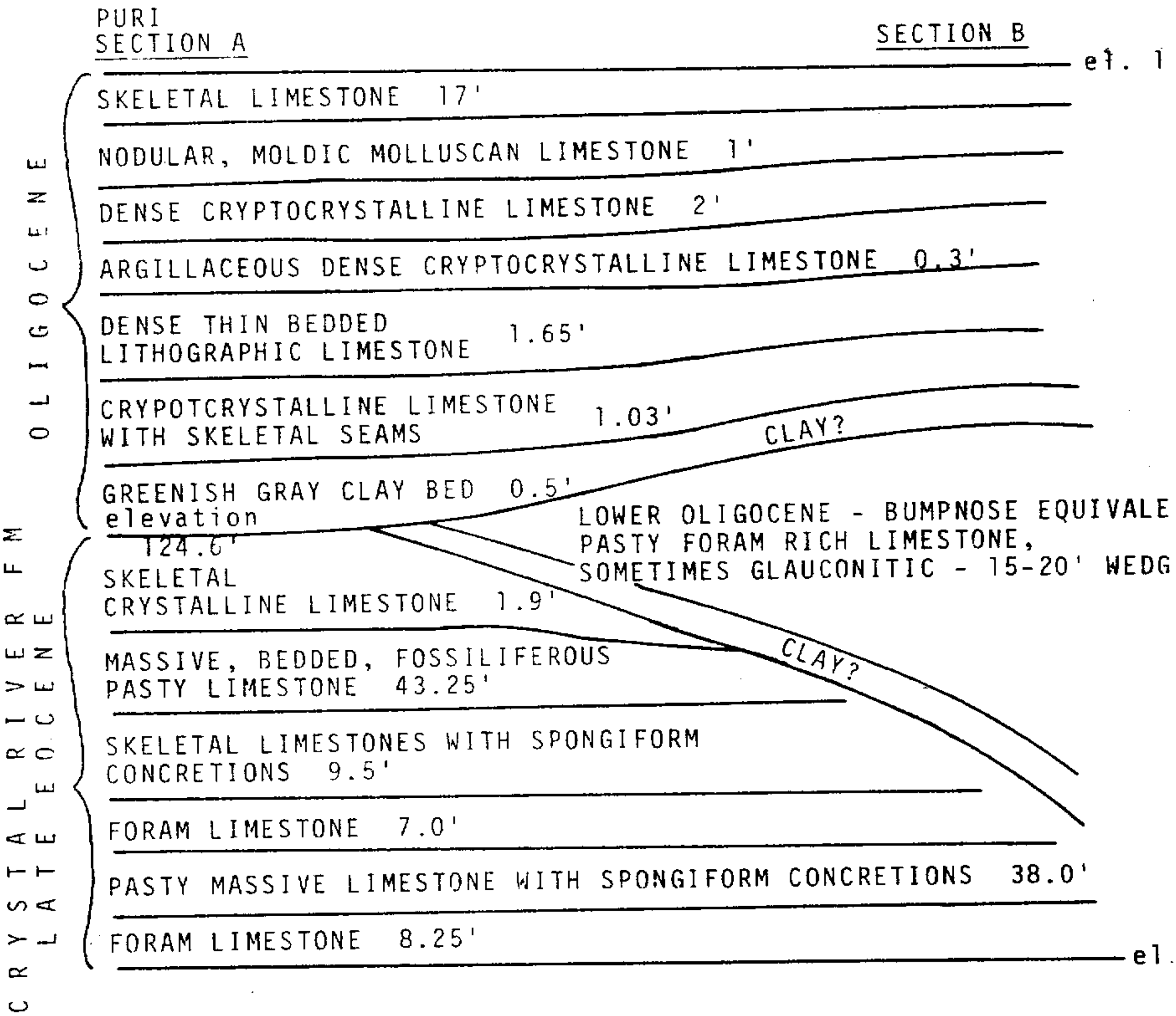
transportation. Interesting cylindrical limestone artifacts which resemble holothurians in shape are abundant in some beds. These "holothurians" as referred to by most Florida field geologists probably are not the remains of holothurians because they lack internal spicules. They are normally hollow or infilled by concentric layers of sediments with different textures than the outside, they do not appear to be concretionary by precipitation in nature. Perhaps they are sediments bound in some form of algae, sponge, or other soft tissued organism. Another explanation might be some type of burrow infilling with the original burrow wall of different texture, usually coarser. This may also explain the many volcanoe shaped specimen. Whatever these structures are, they are normally concentrated in specific beds. In this pit they occur in two beds.

Puri included the *S. vernoni* zone in the Crystal River Formation and correlated it with the *Asterocyclina* zone of Jackson County in northern Florida. Joe and I asked repeatedly "why?", but he was unable to remember and told us that it was probably because both were at the top of their respective sections. At every place that I have seen *S. vernoni*, it has been associated with Oligocene fossils such as *C.* of. *rogersi*. In Bob Vernon's well description from which he collected the type specimens, he reported *Lepidocyclina chaperi?* with the *Spirulaea* specimens. I checked the samples (W-345, 150-160 feet, Polk County) and agree with him that it is "*L. ocalana*" but I question these because of the nephrolepidine primary chambers in the leps and because it has been common practice by many people to call all leps "*ocalana*" without sectioning them. It is possible though that both species occur in the well, since they do occur in the Bumpnose together in northern Florida, (Moore, 1955).

I believe *S. vernoni* is an Oligocene form. I have found it many times at the surface with Oligocene fossils, but never in the Crystal River with Eocene forms; I have not found it in the *Asterocyclina* Zone.

Table 3 summarizes the biostratigraphy and common fossils of these units.

The Ocala beds dip to the east, their highly irregular karst surface is covered by Oliocene beds that first drape over the irregularities and then lap up against the exposed Eocene beds further to the east. The later Oligocene beds depositional dip to the west. Since their deposition in a shallow marine bank or carbonate ramp setting they have been uplifted and eroded on their exposed surface as well as by marine and coastal processes during their elevation producing the western scarp or the Brooksville ridge which may have been aided by structural weaknesses produced by faulting reported by Vernon, 1951.



NOTE: not to scale

FIGURE 12: Comparison of the beds of Puri's type-section with that of Section B of the report.

Table 3: Biostratigraphic, lithostratigraphic, and nomeclatural guide for Suwannee to Avon Park Formations*

STAGE	FORMATION	REMARKS	BIOSTRATIGRAPHIC COLUMN	ADDITIONAL FAUNA	LITHOSTRATIGRAPHIC COLUMN
Vicksburg = Early Vicksburg Red Bluff	Suwannee Limestone	Cooke and Mansfield (1936) for beds along river near Ellaville. Popular useage in peninsular Florida refers to undifferentiated Oligocene	DICTYOCONUS subzone *Dictyoconus* cookei *D. floridana* *Cardium* zone *Cerithium*	*Rhyncholampas gouldii*	moldic bivalve beds echinoid beds laminated skelatal or pelloidal beds lithoclastic beds *Dictyoconus* beds chalks(?)
	Bumpnose Limestone	Moore, 1955. Equal to Red Bluff Clay and Forest Hill Sand to west.	*Lepidocyclina chaperi* zone =*Turritella martinensis* *Spirulaea vernoni* *Spondylus dumosus* *Wythella eldridgei* *Chlamys incertae*	*Aturia alabamensis* *Clypeaster* cf. *C. rogersi* *Ostrea vicksburgensis* *Chione* sp	argillaceous beds glauconitic beds lep sands chalks moldic molluscan beds
Jackson	Crystal River limestone	Crystal River Formation (Puri, 1957), restricted Huddlestun and Toulmin, (1965).	*Nummulites willcoxi* zone =*Asterocyclina* zone *N. vanderstoki* zone *Lepidocyclina-Pseudophragmina* zone *Spiroloculina newberryensis* zone	*Weisbordella cubae* *Eigopygus wetherbyi* *Chlamys* aff. *spillmani* *Amusium ocalanum* *Chlamys indecisus*	*Nummulites* beds Lep beds chalks (?) moldic molluscan beds skeletal beds lithoclastic beds oyster and pecten beds
	Williston Limestone	from Puri (1957), extended downward to include all strata formerly in Lower Ocala of Applin and Applin (1944) by Cole and Applin (1964).	*Nummulites willcoxi* zone *N. heilprini* zone =*Spiroloculina seminolensis* and *Amphistegina pinarensis cosdeni*	*Oligopygus haldemani* *Eupatagus antillarum* *Periarchus* sp *Platyoptera extenda*	Miliolid beds lithoclastic beds fragmented Periarchus bed moldic shell beds
Claiborne	Avon Park Limestone	Cole and Applin (1964) recommend Inglis and Avon Park Formations should be lumped	*Dictyoconus floridanus* zone *Lituonella floridana* zone *Peronella dalli* zone	*Oligopygus phelani* *Cassidulus globosus* *Eupatagus clevei* *Bellatara* spp *Turritella fischeri* *Phacoides megameris* *Corbula* cf *densata* Shrimp claws	dolomites algal beds laminated mud beds lignitic beds graded skeletal beds miliolid beds echinoid beds

*compiled from numerous sources (Hunter 1972, 76 a, b; Banks 1976)

STOP NO. 5: FLORIDA LIMEROCK GULF HAMMOCK MINE

This stop is very interesting for several reasons; much of the limestone has been dolomitized. The rocks represent subtidal to supratidal conditions, and these are the oldest rocks known to crop out in the state of Florida. Unfortunately, mining is by drag-line below the water table, therefore no in situ rocks or outcrops occur at this stop. Dennis Murfa, the company geologist, will take us out to the quarry, and supervise spoil collecting. Unique rock specimens from this quarry yield plant fossils closely related to the marine grasses *Thalassia*, *Halodule*, and *Sarinpodium* as well as mangrove leaves; Laminated crusts and supratidal dolomites; crab and root bioturbation; recrystalized skeletal and pel-limestones; and dolomites and mudstones. We will then examine cores from the quarry in order to observe the vertical sequence. It is noteworthy that a hundred or more cores exist from this quarry which covers several sections. This coverage has permitted Dennis Murfa to conclude (pers comm): lateral facies are extremely variable, there are several repetitive facies, but only one bed (a cream to light tan dense Mg rich limestone) is continuous throughout the explored region, and the amount of hard rock varies considerably from one location to the next. The continuous bed generally overlies a soft chalky white limestone.

Randazzo and Saroop (1976) report on the sedimentology and paleoecology of the Inglis and Avon Park Formations from the Crystal River area. They conclude that cores reveal multiple regressive-transgressive sequences or cycles, aerial exposure and subsequent diagenesis. Biomicrite-poorly washed biosparite (I), dolomitized biopelmicrite-biosparite and algal dololithite (II) and pellet-intraclast bearing biosparite (III) were the three major facies which correspond to the following environments: shallow basin covered by marine grasses and dasyclad algae, supratidal and intertidal resembling Holocene mudflat deposits, and shallow marine bank environments respectively. This analysis seems appropriate and fits field data and core observations. However, as always, there is room for continued speculation! For example, Randazzo and Saroop identify several fining upward sequences which they interpret as grass bed fining upward sequences as reported by Ginsburg and Lowenstam (1958). Closer looks at these sequences allow room for re-interpretation of many of these sequences as wrack and storm deposits. Criteria for this interpretation are as follows: absence of rhizomes in growth position, most leaf blades of various species lying flat such as mangrove and *Thalassia* or its precursor, and recurrent fining upward sequences on a shell lag without evidence of trapping or sediment binding.

Randazzo, Stone, and Saroop (1977) discussed the diagensis of these beds and concluded that dolomitization occurred by two methods - supratidal penecontemporaneous dolomitization and postdepositional dolomitization by Mg rich ground waters. Cementation occurred in multiple stages as did dissolution and dolomitization by ground water probably reflecting changes in sea level and associated water chemistry.

In local areas erosional outliers of white soft limestones containing typical Williston fossils can be found on the indurate, highly irregular upper surface of the Inglis-Avon Park dolomites. This contact represents a provincial hiatus (Huddlestun et al, 1974). The contact here is approximately 5-10' above sea level. It is interesting to note that although numerous faults (Vernon, 1951) have been utilized to explain stratigraphic relationships across the peninsular arch, the Williston-Inglis contact at Stop No. 6 near Martin-Anthony Road and U.S. 441 intersection rests within 10-20' of the elevation of the contact at Stop 5. Therefore, it may be concluded that vertical displacement along faults has been minimal, that faults are associated with karstification and are local in nature, or that net vertical displacement across the several proposed blocks forming the Brooksville Ridge and adjacent areas into the Ocala Hills is near zero. It might be argued that karstification occurs along faults therefore explaining the linear orientation of karst lakes and other features; however, carbonate facies which are normally parallel to shoreline in distribution may also control karstification.

STOP NO. 6: SANITARY LANDFILL ON MARTIN-ANTHONY ROAD

Along the southern wall of this old limestone quarry is exposed a complex geological section which includes the Crystal River Formation (Jackson Eocene), an Oligocene erosional unconformity and associated subaerial laminated crust and silicified boulder zone, oyster rich possibly argillaceous limestone generally reported as Tampa limestone but more than likely equivalent to the Shoal River (Middle Miocene) in western Florida, and a quartz sand with clay stringers infilling a sinkhole which contains rare Miocene vertebrate fossils (Figure 13).

Only the top 15' of the Crystal River is visible at present because fill place during sanitary operations covered an additional 20-30' of exposure at this end of the pit. At the east end of the south face a sinkhole is exposed descending into the top of the Crystal River limestone which contains abundant *Lepidocyclina ocalana* and *Amusium ocalanum*. The sinkhole is at least 100' wide at the top and the bottom has never been exposed. The sinkhole is infilled with white, well sorted, quartz sand with occasional greenish clay pockets and rare terrestrial vertebrate fossils. Manatee bones, or dugong more than likely, are also found in the sinkhole infilling, but probably are derived as a lag from dissolution of limestone during karstification.

Covering the Crystal River and sinkhole filling is an additional 15-20' of oyster rich limestone equivalent to the Shoal River in western Florida. This correlation is based upon molluscs, especially the oysters and pectens which do not correspond to those found in the Tampa limestone (Muriel Hunter, personal communication). Between the Crystal River and Shoal River limestones is a zone of silicified limestone boulders which form a more or less continuous bed. The boulders contain abundant leps. No *Rhyncholampas gouldii*, an Oligocene echinoid from the Suwannee Limestone, were found suggesting that the boulders represent a part of the Crystal River that is missing. Further north in western Alachua County silicified boulders containing abundant *Rhyncholampas gouldii* are found on the Crystal River surface (Williams, Nicol, and Randazzo, 1977). Western Alachua County, however, is lower in elevation. An apparent subaerial laminated crust is also found along the top surface of the Crystal River and can best be observed along the western rim of the sinkhole.

It is interesting to note that the top of the Crystal River (124' above msl) to the west (Stop No.4) is 20-30' higher than the top of the Crystal River at this stop (approx. 100') and much of the upper Crystal River is overlain by Oligocene deposits. This may suggest that Oligocene seas did not completely inundate Peninsular Florida. A series of islands or a nearly continuous ridge was exposed and eroded during the Oligocene. It is possible that marine sediments that may have been deposited were subsequently eroded with the top of the Crystal River. This erosion may be related to the development of the Ocala Arch. An interesting point is whether the arch formed before or after deposition of the Shoal River beds which range upwards to approximately 120' in elevation. A model which may explain the above observations recognizes that the Florida platform has continuously subsided at a greater rate in the south than in the north (although the rate has not been constant) and assumes that the rate of subsidence has not been the same for the eastern and western margins of the platform. Furthermore, through geological time, the subsidence has not been the same for the eastern and western margins of the platform. Furthermore, through geological time, the subsidence rates have been greater in the west than the east, a reversal, Ocala Arch. Another reversal probably occurred in the Pliocene. This model requires that the Florida platform behaves like a coherent block.

This period of non-deposition at Stop 6 is expressed as an erosional karst surface in Crystal River limestones. Oligocene and Early Miocene marine sediments are lacking here but exist at lower elevations to the north and east and at higher elevations to the west and south (towards Brooksville). The Oligocene deposits to the west were elevated during Hawthorne time and eroded along the western scarp of the Brooksville Ridge while sediments rapidly filled the eastern portion of the platform as it differentially subsided more rapidly. This subsidence occurred simultaneously with a major regression which accounts for the change in deposition from Marine to non-marine during the Miocene. This sequence was exposed at the NE roadcut of U.S. 441 and the Martin Anthony Road: 20' of marine limestones and clastics at base are Tampa, approximately 20' of non-marine clay, and approximately 15' of phosphatic clayey sands of the Hawthorne (afer Brooks, in Brooks, Pirkle, and Fountain, 1967).

FIGURE 13: Photograph of the sinkhole and section at Sanitary Landfill or Martin-Anthony Road.
A: Crystal River Formation.
B: Silicified and subaerial laminated crust zone.
C: Shoal River Formation.
D: Sinkhole infilling.

STOP NO. 7: LOVE BONE BED

By: Professor David Webb
Florida State Museum
University of Florida

I. INTRODUCTION

The Love Bone Bed has produced the richest sample of late Miocene vertebrate life in eastern North America. It is also the first Clarendonian age vertebrate fauna east of the Mississippi River. Other significant late Miocene sites in Florida have all been Hemphillian in age (Webb and Tessman, 1969; Tedford et al., 1979). The fossil bones and teeth occur in phosphatic sands and clays that accumulated in what was then a coastal stream on the west side of Central Florida. The vertebrate sample includes terrestrial, freshwater and some estuarine taxa. The purpose of this paper is to provide an overview of this rich vertebrate fauna, its age, ecology and occurrence.

II. THE LOVE BONE BED

The Love Bone Bed is situated in western Alachua County just north of the town of Archer with its basal elevation at about 20 m above sea level. It was discovered in 1974 by Mr. Ron Love while tilling an okra crop on his land at the northern edge of Archer, Florida. A tibian of *Teleoceras* that he presented to the Florida State Museum warranted additional investigation. Other scraps of bone were visible at the surface including interesting concentrations of terrestrial and aquatic vertebrates. Auger cores 3 m deep were drilled on an 8 m grid system, and using this information, the fossilifgrous concentration was delimited by trenching with a backhoe. A small area encompassing roughly 900 m^2 was outlined. The S-shaped outline of the stream deposits is now represented by the excavated quarry (Figure 14). Since 1974, the site has been worked by Florida State Museum field crews, expending over 3,000 person days and about 20 days of backhoe and bulldozer work over a five-year period. During December 1978 and January 1979, a detailed plane-table survey was completed to precisely locate the fossiliferous concentration and define the paleo-channel.

The Love Bone Bed richly samples late Miocene vertebrates from estuarine, freshwater and terrestrial habitats in north central Florida. Over 80 taxa are reconized of which about half are mammals. Further study of microvertebrate samples is expected to bring the fauna to at least 100 species.

The site consists of fluvial sediments of the Alachua Formation that fill stream channels cut into the Late Eocene Crystal River Formation. The fluvial sediments represent a single depositional cycle and fine upward from coarse phosphatic sands and gravels to orange clays and clayey sands. Taphonomic data suggest a flow from north to south.

The age of the Love Bone Bed Local Fauna is very late Clarendonian as indicated by the stage of evoluation of several mammal species, by the presence of the Eurasian immigrant genus *Beckia*, and by the absence of early Hemphillian immigrants including ground sloths and bears (see Figure 15).

About 40 percent of the vertebrate sample (by weight) consists of lentic turtles and garfishes, apparently transported from perennial marshes. An estuarine fauna is marginally represented by sharks, various bony fishes and two species of marine mammals. Evidently late Clarendonian sea level approached the elevation of the Love site (about 20 meters). The diverse terrestrial fauna includes elements of a streambank community, an open-country community and a deciduous forest community. The rich samples of sylvan and lentic vertebrates as well as the presence of estuarine vertebrates readily distinguish the Love Bone Bed from otherwise broadly comparable local faunas in the midcontinent. This fauna is also notable for some taxa of possible neotropical affinities, including certain Procyonidae, Cricetidae and an early member of the Laminae.

In north-central Florida two formation names, the Hawthorne and Alachua, are used for extensive pre-Pleistocene clastic sediments that were deposited on the early Tertiary carbonate surface. Both of these units are highly variable in lithologies and are often geographically restricted, i.e., isolated sinkhole fills, and therefore it is difficult to distinguish between them in every instance.

The Hawthorne Formation was originally described by Dall and Harris (1892). Although never specifically designated, presumably the "type" section was from a phosphate pit near the town of Hawthorne in eastern Alachua County. More recently the Hawthorne Formation is associated with the "neotype" section from Devil's Millhopper in central Alachua County (Williams, Nicol, and Randazzo 1977). Puri and Vernon (1964, p. 145) stated that the: "Hawthorne perhaps is the most misunderstood formational unit in the southeastern United States. It has been a dumping ground for alluvial, terrestiral, marine, deltaic, and prodeltaic beds of diverse lithologic units in Florida and Georgia ..." In some cases, the Hawthorne Formation has been "recognized," by its "Miocene" vertebrate fauna.

Dall and Harris (1892) are credited with the original description of the Alachua Formation. Since that time, this unit has also commonly been referred to as the Alachua "Clays" (e.g., Leidy and Lucas, 1896). The type locality of the Alachua Formation is at Mixson's Farm, a highly fossiliferous sinkhole fill about 3 km north of the town of Williston in Levy County (Webb, 1964). The Alachua Formation is generally considered to be a predominantly non-marine blue-gray and tan-brown clay with interbedded and poorly-indurated cross-bedded phosphatic sands. Some workers, not following accepted stratigraphic procedure, have "differentiated" the Alachua Formation by its "Pliocene" vertebrate fauna from the "Miocene" vertebrate fauna of the Hawthorne Formation. In western Alachua County the Hawthorne and Alachua Formations are not laterally continuous, but they can be distinguished on lithological criteria (Williams and others, 1977). In this region, the Hawthorne Formation is predominantly marine whereas the Alachua Formation is predominantly non-marine. At the Love site, the presence of brown clays and cross-bedded phosphatic sands is diagnostic of the Alachua Formation.

III. STRATIGRAPHIC SECTION

The stratigraphy at the Love site is complex, reflecting the marked spatial and temporal changes in environment of deposition associated with a meandering stream and its overbank deposits. The clastic deposits of the Alachua Formation at the Love Bone Bed form a lenticular body of variable thickness cut into the underlying Crystal River Formation. Figure 16 is a generalized section along survey line 30S which transects the thickest section (about 3 m). This section apparently crosses the center of the paleostream channel at the base of a plunge pool, and gives some idea of the complexity of the site stratigraphy. Farther west, a pocket of interbedded clays and clayey sands contains fossils of mainly aquatic vertebrates and was apparently an area of quiet water deposition separated from the main channel by large limestone blocks. The main channel lies immediately west of a boulder bar and farther east there is a shallower channel.

In Alachua County the late Eocene Crystal River Formation underlies the Alachua Formation. This carbonate unit is the uppermost member of the Ocala Group and it is a soft, granular, bioclastic limestone (Williams and others, 1977). The Crystal River Formation lies at, or very close to, the surface in much of western Alachua County, forming a karst plain about 20 to 25 m in elevation. In test holes drilled around the Love site, the Crystal River Formation was usually encountered within two meters of the surface. Reworked marine invertebrates from this formation are occasionally found in the clastic deposits of the Love site. Large blocks of this limestone, some two meters long, are also found within the clastic deposits, presumably the result of limestone bank collapse along flooded stream channels. The coarsest clastic particles of the Alachua Formation are contained in a channel bordered by limestone or limestone rubble. At the contact zone between the stream channel deposits and the Crystal River Formation, the limestone is diagenetically altered to a green or pink clay. The green clay varies from one to several centimeters in thickness and blankets the top of the limestone wherever it has been excavated or exposed in test pits. Above it, the sediments of the Alachua Formation may be divided into three units.

The basal unit of the Alachua Formation at the Love Site is a massive bone breccia, consisting mainly of turtle and garfish material. There is also abundant mammalian material, including concentrations of larger skeletal and cranial elements of giant tortoise, elephant, and rhinoceros, which are often disarticulated or semi-disarticulated, broken or crushed. Large limestone boulders are most common in this unit. A sediment sample, excluding large bone fragments, had a mean size of -1.2 ø. The inclusive standard devision of 4.36 ø indicates that the sediment is poorly sorted. The sediment distribution is bimodal. The primary mode is -5.25 ø. The coarsest fraction of the sediment samples is composed of bone fragments, mainly pieces of turtle shell. The secondary mode is 2.75 ø. The finer fraction is composed of clean, fine-grained, quartz sand. Approximately 5 percent of the sediment is silt and clay. A cumulative curve drawn for this sample shows a high percent of the traction population in these sediments.

This basal unit (unit 1) of the Alachua Formation is interpreted as a channel lag deposit, forming at the base of a plunge pool. It is one meter thick at grid coordinate 30S X 30E, and regularly attains a half meter elsewhere at the base of the main channel south of 20S. The bones in this unit are often worn and abraded and the large bones, especially, are broken. Channel lag deposits represent residual concentrations of coarse material that accumulate as lenticular patches in the deeper part of the channel. Bone is concentrated as coarse sediment in channel lag deposits.

At the base of the channel at coordinates 25S X 25E is a concentration of well rounded and darkly stained pebbles and cobbles, bone fragments and some horse teeth. It is from this facies that unworn teeth of *Carcharodon megalodon*, an extinct relative of the great white shark, and a tooth and unworn skeletal elements of *Metaxytherium*, a seacow, have been recovered. Channel lag deposits occupy the lowest part of a channel or point bar sequences.

The middle sedimentary unit (unit 2) is composed of less than one meter of thin to very thin bedded, alternating, discontinuous, cross-bedded darker coarse phosphatic and lighter colored, finer grained sand. In places, this unit forms scour and fill troughs between larger limestone boulders. When this occurs, dips of the beds appear to be controlled by the shape and placement of the boulders. Along the southwest margin of the deposit, dips appear to be controlled by the limestone bank (i.e., the beds dip to the southwest). Bones that occur in unit 2 seem to lie mainly on the bedding planes. This unit is highly fossiliferous and produces most of the rich microvertebrate sample.

A sample taken from a darker layer of unit 2 had a graphic mean size of -0.40 ø. Rounded phosphatic pebbles plus some bone fragments form most of the pebble to coarse sand fraction. The fine and very fine sand fraction is mainly composed of quartz grains. Five percent of the sample is silt and clay. The sediment is poorly sorted (σ_i = 1.44 ø), coarsely skewed (SKi + 0.23) and very leptokurtic (Kg = 1.76).

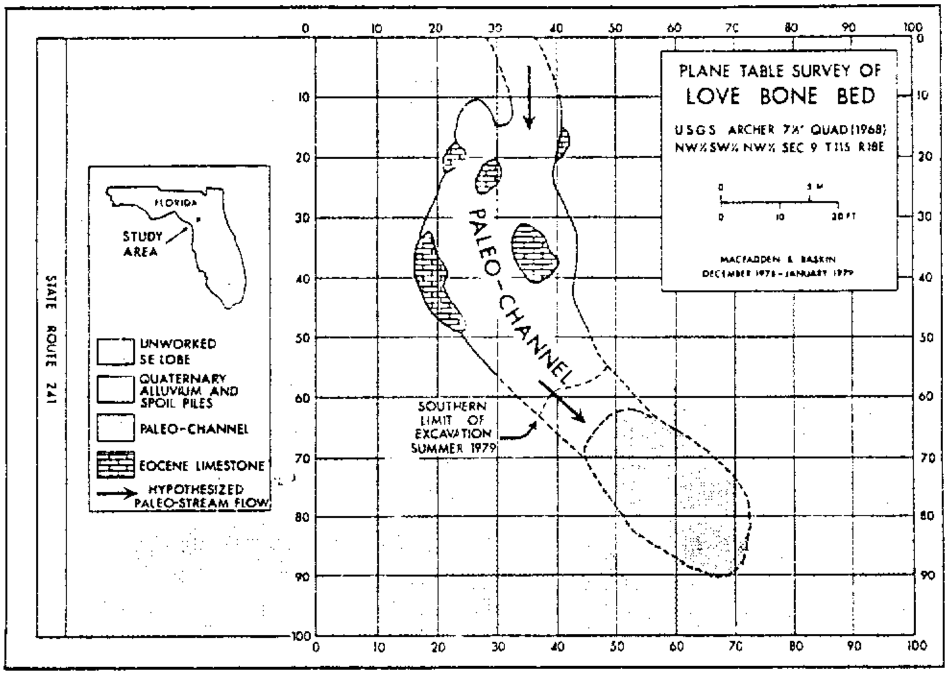


Figure 14. Plane table survey of Love Bone Bed.

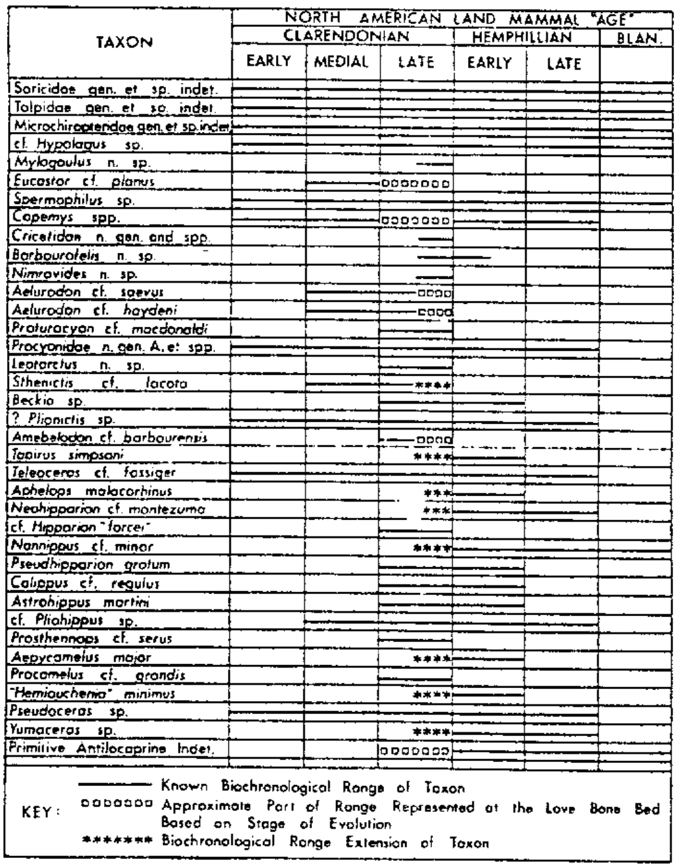


Figure 15. Stratigraphic ranges of selected vertebrates from the Love Bone Bed.

A sample taken from a lighter colored bed of unit 2 had a graphic mean diameter of 2.9 ø. The sediment is poorly sorted, (σ_i = 1.62), symmetrical (SKi = 0.02) and very leptokurtic. Twenty percent of the sample consisted of silt and clay.

Unit 3 is a massive tan, grading to orange, clayey sand. Although not as fossiliferous as the underlying units, the material from this unit is often better preserved and shows much less evidence of abrasion. Several nearly complete turtle shells have come from this unit. A sample from unit 3 had a graphic mean size of 3.1 ø. The sediment is poorly sorted (σ_i = 1.57 ø), coarse skewed (SKi = 0.12), very leptokurtic (Kg = 2.49) and contains 18 percent silt and clay. Another sample has a graphic mean diameter of 1.5 ø, is poorly sorted (σ_i= 2.83 ø), coarse skewed (SKI = 0.29) and consists of 19 percent silt and clay. The larger mean size is caused by bone fragments in the sample. This unit is continuous both horizontally and laterally with the underlying units. Laterally the coarser cross-bedded and lag deposits grade into this orange clayey sand. It can either lie uncomformably on top of unit 2, producing an irregular contact surface, or horizontally truncate the crossbeds of the lower unit.

The clastic deposits of the Love site seem to represent a single cycle of deposition. Cut and fill structures are restricted to trough cross-bedded unit 2. Sediments fine upwards in every section. There has been no evidence of channeling cut into unit 3. Unit 3 probably represents the overbank deposits of the stream channel. As the stream migrated laterally this unit covered the lower lag and bar deposits. The unbroken trend toward successively finer sediments and the absence of rechanneling suggest that the Love Bone Bed accumulated in a single depositional cycle, which must represent a brief interval of geologic time.

Much of southwestern Alachua County, including the Love site, is mantled by a thin layer of sand. These sands generally have been interpreted as Pleistocene dune deposits. A sample of this surficial sand had a graphic mean diameter of 2.6 ø. The sample is moderately sorted (σ_i = 0.92 ø), fine skewed (SKi = 0.19) and mesokurtic (Kc = 1.05). The sorting is much poorer than that reported for dune and beach sands, and similar to those of modern channel sands.

IV. PALEOECOLOGY

The Love Bone Bed accumulated in a moderate sized meandering stream. Although this interpretation is based on sedimentary fabrics, textures, and bone orientation and the geometry of the site, it is amply confirmed by the fauna itself. The great majority of the vertebrate remains are freshwater aquatic taxa, the garfish, bowfins, and turtles being especially abundant. A few articulated (though incomplete) skeletons of garfish with scales in place have been found in silty orange clay facies (notably at 35 S, 35 E). A very common facies at the site is the "gar Scale breccia". Typically this facies consists about half of disarticulated and disoriented gar scales and about half of clavey orange sand of fine to medium grade. Complete turtle shells are also not uncommon in the clavey sand and sandy clay facies, but only one Trionyx shell has contained an associated skull.

An attempt has been made to distinguish different aquatic facies within the stream deposits at the Love Bone Bed. Much the most distinctive facies has been recognized at the base of the section (immediately above the limestone and associated clay residues): it is a silty green clay (located from about 25 to 35 E by about 25 to 30 S on our grid). It yields a distinctively estuarine vertebrate sample including relatively numerous dugongid ribs, several large shark teeth and some cetacean fragments. Elsewhere throughout the site some rare estuarine specimens also occur but they are invariably mingled with the far more abundant freshwater specimens. The only relict of an estuarine facies that can be distinguished here is apparently a single lens at the base of the late Miocene sedimentary record.

Another more subtle distinction within the freshwater facies can be based on different abundances of fast-water versus slow-water species of turtles. A plot of the relative frequencies of nuchal bones representing *Pseudemys* on the site grid produces a pattern suggestive of the distribution of cut banks and slip-off slopes in a meandering stream. This pattern will be further tested when the southern third of the site is excavated.

Another approach to such ecological distinctions is to census the vertebrate fossil sample from each sedimentary facies. A preliminary study of this nature was carried out by Mr. Chris Brecher who compared the contents of a cubic meter of the greenish sandy clay facies to a cubic meter of the gray phosphatic gravelly sand facies. These represent the fine and the coarse extremes of the most frequently encountered fossiliferous facies at the Love Bone Bed. Mr. Brecher sieved and weighed the sediments and counted and identified the vertebrates in each sample.

In both samples freshwater aquatic taxa, led by garfish, bowfin and turtles, predominate. No frequency differences clearly distinguish what might be expected to be the faster water sample from what might be expected to be the slower water sample. However, two other differences are evident. First, the relative abundance of vertebrate fossils is much greater in the finer sample. Secondly the percentage of terrestrial vertebrates out of all vertebrate remains is considerably higher in the coarse channel facies. This agrees well with the general experience of excavators at the site who regularly observe that the coarse channel fills usually produce the largest and the most interesting terrestrial specimens. A similar observation has been made regarding the terrestrial microfauna: the most productive non-fish small vertebrates samples are regarded as the finer fractions of the medium to coarse units.

The terrestrial fauna itself, though much less abundant than the aquatic fauna, is more diverse. Evidently the terrestrial vertebrates represent several terrestrial communities. Consequently many of the vertebrate taxa, presumably those mainly confined to small or remote communities, are rare or absent. The three terrestrial communities that are moderately to well represented by vertebrate taxa are the following: (a), the stream bank and oxbow margin; (b) stream border forest; and (c) prairie and turkey-oak savannah.

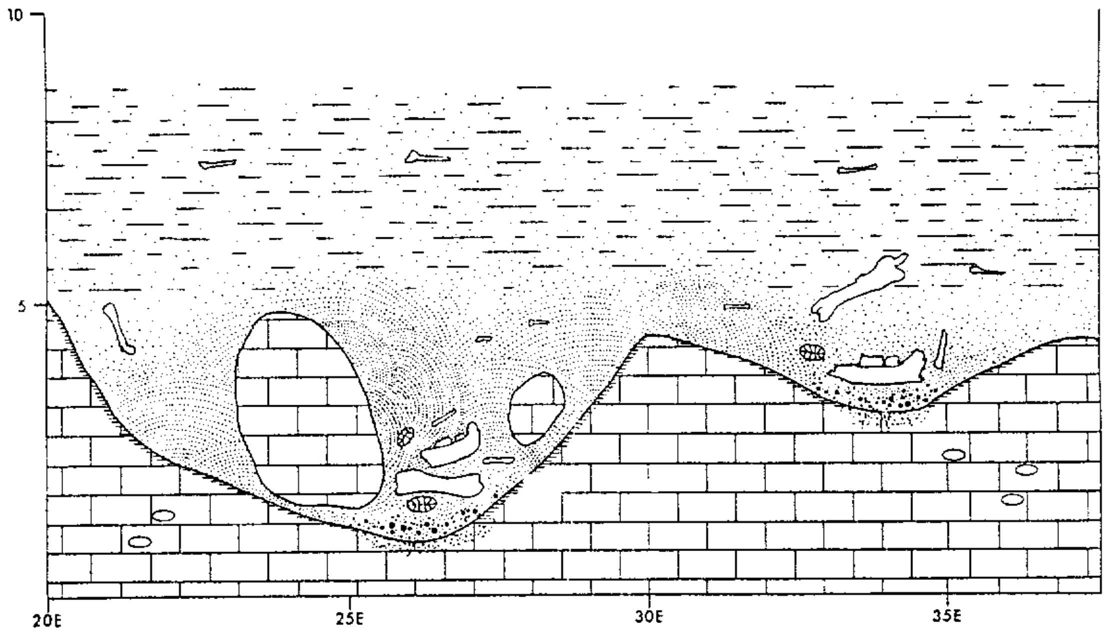


Figure 16. Generalized stratigraphic section along survey line 30S.

STOP NO. 8: DEVIL'S MILLHOPPER STATE GEOLOGICAL SITE.

The Devil's Millhopper is a collapse sink that cuts through at least 115' of Hawthorne beds to the Ocala limestone. The Ocala limestone lies within the range of the oscillatory water table at this locality and therefore is not visible at all times.

The Devil's Millhopper is found in the Northern Highlands Plateau physiographic province which exhibits a relatively flat, low relief surface that ranges in elevation from close to 200' along the western edge to 145-150' along the eastern margin. The Devil's Millhopper is located approximately 6 mi. NW of Gainesville, Florida. The highlands Plateau is composed of 100-150' of Hawthorne clays and sands and 0-30' of Pleistocene undifferentiated sands and clays which rest on the gentle eastward dipping Crystal River limestone (Figure 17). The clays of the Hawthorne are an effective barrier, prohibiting downward migration of surface waters. Subterranean karstification creates numerous depressions in the land surface creating cypress swamps or heads over the locally perched water tables. Continued karstification beneath the Hawthorne enlarged the size of the cavity creating the conditions for collapse of the roof, thus producing sinks such as the Devil's Millhopper. Where no clastic overburden exists collapse sinks are less commonly observed in this area.

The section at the Millhopper has been described many times (Cooke, 1945; Pirkle 1956, 1958; Puri, Bishop, and Stewart in Puri and Vernon, 1959; Thompson and Floyd in McClellan, 1962; Pirkle, et al., 1965; and Williams et al., 1977 as well as others) often with considerable differences in the details of the descriptions. This is the result of occasional slumping of the walls of the sink which exposes, modifies, or covers portions of the sections. The major beds although variable in nature are, however, commonly recognized among most workers. The following section is from Pirkle et al. (1965, p. 39-42) which was chosen because of the spectrum of analyses that are available from their section.

DEVIL'S MILLHOPPER
Section 15, T. 9 S, R. 19 E, Alachua County, Florida
(approximately 6 miles northwest of Gainesville)*

UNIT	DESCRIPTION	THICKNESS (in feet and inches)
Surface Sands		
16	Sand. Loose, gray to white	3' 0"
Hawthorne Formation		
15	Phosphate concentration. Abundant pebbles and grains of phosphorite embedded in a matrix consisting largely of quartz sand and clay. Many of the pebbles of phosphorite are impure limestone or marl fragments in which phosphate has replaced carbonate. These pebbles contain much included quartz sand. Most of the phosphate particles are some shade of white, gray, brown or black	24' 2"
14	Dolomitic limestone to dolomite. Cream to white to yellow, containing in places abundant molds and casts of marine pelecypods and gastropods. Locally quartz sand is an important constituent of the unit. In some places phosphate particles are common	11' 6"
13	Clayey sand. Yellow to yellow-brown with local occurrences of irregular masses of white carbonate Upper 7 inches of unit has a greenish-blue color and a higher content of quartz sand	3' 6"
12	Clayey sand. Upper 1½ feet of unit is dark blue; rest of unit is a light pastel greenish-blue Pyritic	7' 2"
11	Conglomerate. Green to yellow. Unit consists of a mixture of quartz sand, clay and carbonate.	

UNIT	DESCRIPTION	THICKNESS (in feet and inches)
	The pebbles appear to be composed largely of quartz cemented with clay and/or carbonate. The pebbles break down readily when subjected to normal treatments used in making mechanical analyses. Locally black phosphate grains are common. Pyritic	2' 6"
10	Calcareous clayey sand and sandy clay to massive, blocky clay. Light green to blue. Locally phosphate particles are common. In places the unit is highly calcareous. The clay present in this unit and continuing upward through unit 13 has a different appearance from the clay of underlying units and usually has a darker color when fresh. Quartz sand, carbonate, and phosphate particles are more abundant in the upper 10 feet of the unit. Much of the lower 9 feet consists of massive, blocky clay with intercalated stringers and small lenses of sand and carbonate. Many of the clay blocks are surrounded by networks of quartz sand and carbonate. In the lower foot of the unit quartz sand increases. Because of slumpage some of the sediments in this interval could not be sampled or observed. Thus no attempt was made to subdivide these sediments. Pyritic	20' 6"
9	Massive clay. Gray to greenish-gray, blocky with networks of sand and carbonate surrounding some clay blocks and with stringers of sand and carbonate within the clay	3' 6"
8	Clayey sand. Gray, soft	1' 11"
7	"Limestone." White to gray, lithified. Contains remnants of clay blocks. Forms nodular massess and slight ledges upon weathering	2' 0"
6	Clay. Gray to grayish-green to olive green, massive. Clay is blocky with networks of carbonate surrounding clay blocks and with stringers and small lenses of carbonate present within the clay. Carbonate apparently is replacing the clay. Analyses indicate that in some places the massive clay is calcareous and in other places non-calcareous	10' 4"
5	Zone containing intraformational breccias or conglomerates. Upper part of unit is a prominent conglomerate. Near base of unit is another well-defined conglomerate. Several less conspicuous conglomerates are present through the unit. The intraformational breccias or conglomerates consist of various mixtures of quartz sand, clay, phosphate particles, and carbonate. In places these zones contain calcite fossil shells, and angular blocks and rounded	

UNIT	DESCRIPTION	THICKNESS (in feet and inches)
	pebbles of grayish-green clay. The most prominent fossils are *Pecten acanikos* Gardner, *Carolia floridana* Dall, and barnacles	10' 11"
4	Mixture of quartz sand, clay and carbonate. Olive green. As indicated by Thompson and Floyd in an unpublished thesis by McClellan (1962), the distinctiveness of this unit is an aid in locating the units in the lower part of the Millhopper sink	1' 1"
3	Clayey limestone. White, soft. Contains remnants of gray clay blocks, more numerous near upper part of unit	2' 5"
2	Covered slope. An occasional exposure. Approximately 6½ feet above base of unit calcareous sand is exposed. Just over unit 1, clay is exposed. Cannot be certain if these exposures represent materials in place or slumped sediments	9' 1"
1	Sandy limestone. Locally dolomitic. White. Rests upon underlying Ocala limestone. In places dense, dark colored, with stringers of quartz sand. Contains occasional blocks of gray clay. Parts of this unit are highly silicified. Where the silicified portions rest upon Ocala limestone, that limestone is often silicified	3' 2"
	TOTAL DEPTH	116' 9"

*Measured by E. C. Pirkle, Fred Pirkle, and W. H. Yoho, early spring, 1962.

Dall (1892) proposed the name Hawthorne for the beds exposed in the Devil's Millhopper and Brook's Sink as well as other places. He used the original descriptions of L. C. Johnson (with acknowledgements). The Devil's Millhopper and Brook's Sink have subsequently been made cotype localities for the Hawthorne Formation (Puri and Vernon, 1964).

The Hawthorne is present throughout most of Florida with the exception of the Ocala uplift area. Hawthorne sediments consist of quartz pebble sand, sand, silts, and clays, calcitic and dolomitic carbonates, limestone clasts, sand and pebble phosphate, and clay lumps. Hawthorne units are marine and non-marine beds that often exhibit great vertical and lateral facies variability. Pirkle (1958) and Pirkle et al. (1965) discuss the lithology of the sediments found in the Devil's Millhopper Section. Several interesting features have been described; silicified clays, gradation of clays into lenses of limestone and sandstone, apparent replacement of limestone, and a characteristic heavy mineral suite. Hawthorne sediments contain garnet throughout and relatively large amounts of epidote locally. It is interesting to note that garnet is absent in Citronelle sediments and epidote is usually absent or rare (Pirkle et al., 1965). This change in mineral suite should reflect a change in the source rock or possibly changes in weathering and erosional and transportation processes. The onset of marine deposition of the Hawthorne marked a major change in sediment regime from carbonate dominated sediments of the earlier Tertiary to siliclastic sediments, which has remained the dominant sediment regime until the present in all but the southern most part of the peninsula.

Although alluvial, terrestrial, marine, deltaic, and prodeltaic beds have been placed in the Hawthorne, most Hawthorne sections contain thin beds or lenses of marine fossils throughout the section. This has led to the conclusion that most of the Hawthorne was deposited in marine or closely related environments. Undoubtedly many marine beds do exist, but many of the marine units may contain reworked shells from older units thus explaining the poor preservation and incomplete faunas. Phosphate pebbles are also often associated with the marine shell casts and molds which are often themselves phosphatized suggesting an erosional or lag type origin for these beds. Also, many calcitic and dolomitic lime muds are very likely to have been freshwater calcitic muds and non-marine in origin. These beds often contain gar fish and aquatic turtle bones as well as a few terrestrial vertebrate bones. Furthermore, most recognizable bedding structures such as feston cross-bedding, channel fills and lags, and laminated clays are highly characteristic of point bar, flood plain and channel sediments of fluvial systems. Obviously, much more work must be completed before a full understanding of the Hawthorne will come about. Following the deposition of the Hawthorne, the heavy mineral suites change and stratigraphic and sedimentological evidence suggests fluvial and terrestrial processes are far more important than marine processes in known outcrops.

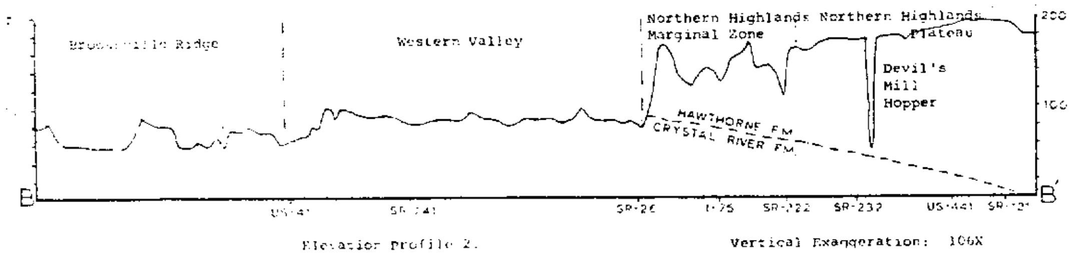


FIGURE 17: Elevation profile through Devil's Millhopper (from Williams, et. al., 1977).

STOP NO. 9: KEYSTONE SAND COMPANY PIT, GRANDIN, PUTNAM COUNTY

Cooke and Mossom (1929) referred to these non-marine clastics as the Citronelle Formation; Brooks and Pirkle in Puri (1960) measured the section in the southeast portion of the pit (Figure 18). Bishop (1956) placed some of these units of Cooke (1945) into the non-marine Hawthorne. Puri and Vernon (1964) refer to the coarse non-marine clastics which include poorly sorted often crossbedded quartz sands, small pebbles, and kaolin clay as the Fort Preston Formation. The upper portion of these beds is usually red or orange, the lower beds white to yellow-grey. They correlate these beds to Alum Bluff age and therefore the Tamiami Formation of southwest Florida (Late Miocene to Middle Pliocene) but these beds probably range into the Pleistocene.

The thickness of the beds varies. Minable kaolin deposits are scattered throughout the section but are limited in extent. They may be up to 30' thick and are often overlain by limestones or green clay. These clays are interpreted as channel fill and floodplain deposits. Crossbedded sands suggest point bars of a fluvial system. Coarse gravels and associated mud lumps are interpreted as basal point bar and channel lag deposits.

Beds of similar lithologies form a massive delta along the Georgia - Florida statelines and extend southward down the peninsula along the east side of the limestone outcrops to the west. The only explanation of why fluvial deposits would be transported down the arch of the peninsula rather than directly to the sea must lie in the construction of a trough formed between the limestone outcrops to the west and the coastal ridge system of the time. This may be analogous to the present St. John's River system with the exception of a northern source. The onset of clastic deposition from the north must be in response to: (1) rejuvenation of the southern Appalachians, (2) increased subsidence of peninsular Florida, or (3) lowered sea level. A combination of these factors is more than likely the case.

For terrigenous clastic sediments to reach peninsular Florida by means other than longshore and beach processes would require that the Suwannee Trough be completely infilled. Why sediment was transported so far south instead of directly to the east or southwest directly to base level more efficiently must be associated with load. Perhaps more sediment was coming from the highlands of the Appalachians than established drainage systems could remove. Also, rainfall must have been high in order for transportation processes to be adequate. The Miocene vertebrate fauna of peninsular Florida is varied but the abundance of camels and horses may suggest a slightly drier climate than present, but not arid. If this is the case, rainfall may have been very seasonal and deposition episodic similar to conditions found in many braided stream regions. This would explain the oxidation of minerals, lack of distinct large channels in the section, and might better fit the vertebrate fossil evidence.

BED	DESCRIPTION	THICKNESS (FEET)
"Citronelle formation"? Plio-Pleistocene		
3	Sand, coarse to medium, tan to buff. Contains abundant quartz and quartzite pebbles. Grades upward into dark grayish brown humus zone..................	7.0
2	Sand, coarse to medium, orange. Abundant quartz and quartzite pebbles disseminate throughout sediments and concentrated in small lenses and stringers....................................	8.5
1	Sand, coarse to medium, white. High content of kaolinite. Quartz grovel and quartzite pebbles occur disseminated throughout the sediments and concentrated in lenses and stringers. To water level......	6.5
Total thickness...		22.0

FIGURE 18: Measured section at Keystone Sand Company, Grandin, Florida. (Section description by Brooks and Pirkle in Puri, 1960).

STOP NO. 10: BUNNELL ROAD CUT

This stop is on one of the highest ridges of the Atlantic Coastal Ridge. From this outcrop eastward several such ridge and swale systems, each successively lower, will be crossed. In better developed systems of short amplitude, major changes in vegetation patterns can also be observed: oak hammock or pine-palmetto on the ridges and myrtle to cypress in the swale depending upon the hydroperiod.

This stop at a ridge crest exhibits shell coquina referred to the Anastasia Formation and an overlying thin quartz sand blanket. The name Anastasia Formation applies to outcrops of coquina rocks which extend along the Atlantic coast of Florida from Anastasia Island (the type locality) southward 150 miles to Boca Raton (Sellards, 1912). Parker et al (1955) reports that the Anastasia Formation forms a thickening eastward wedge shape package of calcareous sandstones, sandy limestones, and coquina with minor amounts of quartz sand and shells. They conclude that the Anastasia was deposited as an offshore bar in the marine evnironment when sea level was higher. Exposed low dunes probably occurred on the surface of the bar.

The outcrop along the road cut exposes low angle beds of arenaceous coquina exhibiting both simple and complex cross bedding: the former is more common (Figure 19). Higher angle crossbedding and clast zones are also common. Parker et al (1955) suggest that most of the Anastasia is an offshore bar, however some evidence points to a beach environment instead. The lack of bioturbation which is common in most offshore facies is missing in the outcropping beds of Anastasia. Low angle planar and simple cross-bedding of well orientated, highly fragmented, well worn and polished shell fragments suggest a higher energy onshore facies. The coquina is nearly always exposed at the crests of ridges often creating, after early cementation by freshwater, a hardpan which is often missing off the crests where quartz sands are most abundant.

Figure 19 shows the six main beds found at this outcrop. The basal bed is an unconsolidated shell coquina which displays low angle eastward dip. Bed 2 is a discontinuous well cemented shell coquina up to 9" thick which lies nearly horizontal. A thicker low angle eastward dipping set composed of well orientated, rounded shell fragments with various amounts of fine to medium quartz sand forms bed 3. Bed 4 is a coquina lithoclastic zone which consists of irregular coarser shell lag and lithoclast bed. Overlying this are well cemented (calcite spar therefore probably freshwater or pheatic environment) beds 5 and 6. Bed 5 is another low angle eastward dipping unit with a coarser shell lag at its base. Bed 6 is again a coquina but exhibiting a higher angle eastward dip, no shell lag is apparent at its base.

The upper 2 beds are lithified and cementation is associated with the fresh water environment. The clasts in bed 4 closely resemble the lithified bed 2, and probably are derived from it. The cement of these two beds has not been closely examined, therefore information is lacking on whether these beds are cemented in the pheatic zone as the upper bed 5 and 6 only at an earlier time or whether the lower bed may be a beach rock cemented in the marine environment (Ginsburg, 1979). The former case would suggest a minor transgression-regression-transgression-regression sequence whereas the later would favor a simplier transgression-regression cycle.

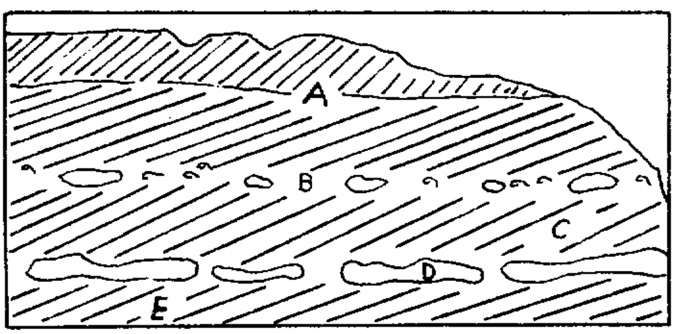


Figure 19. Field sketch of exposed section at Stop 10.
A: Upper lithified cross-bedded units.
B. Coquina lithoclastic zone.
C. Low angle unconsolidated coquina beds.
D. Cemented shell coquina.
E. Basal unconsolidated shell coquina.

STOP NO. 11: LUNCH AT WASHINGTON OAKS STATE PARK (OCEAN SIDE)

We will lunch along the rocky coastline which extends as an outcrop for approximately 12 miles. The rocks are shell coquinas of the Anastasia Formation just as in the last stop. Two major differences occur between these two stops: the elevation, and the observation of "solution holes" and associated root casts and sometimes more resistant infillings which form small positive relief features on the rock surface.

The maximum elevation of these rocks is about 12', generally closer to 8', and about 10' lower than at stop 10. The offshore rock ramp below wave base may have been undercut by waves and may have subsided since deposition and cementation. The ramp definitely shows a slight seaward dip and the rock slab usually is separated from the exposed rocks onshore by major joint seams. Wave erosion during storms and, to a lesser extent, wind blown sands have sculptured the outcropping rocks often forming pipes or "blowing rocks" as they are termed further south. Many small depressions (up to 2' in diameter and sometimes as deep) occur in the surface of the rock which exhibit a reddish oxidized inner surface often covered with root casts. This suggests that trees at one time were firmly rooted in these "pot holes". Whether the trees influenced the development of the pot holes or simply colonized the pot holes because of its organic content is not known.

Some pot holes must have been infilled during subaerial exposure and the infilling lithified. Many of these infillings are more resistant to erosion than the coquina rock, therefore creating small scale positive relief features of completely different lithology on the surface of the Anastasia.

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